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BIOGRAPHICAL MEMOIRS

VOL. XXVIII

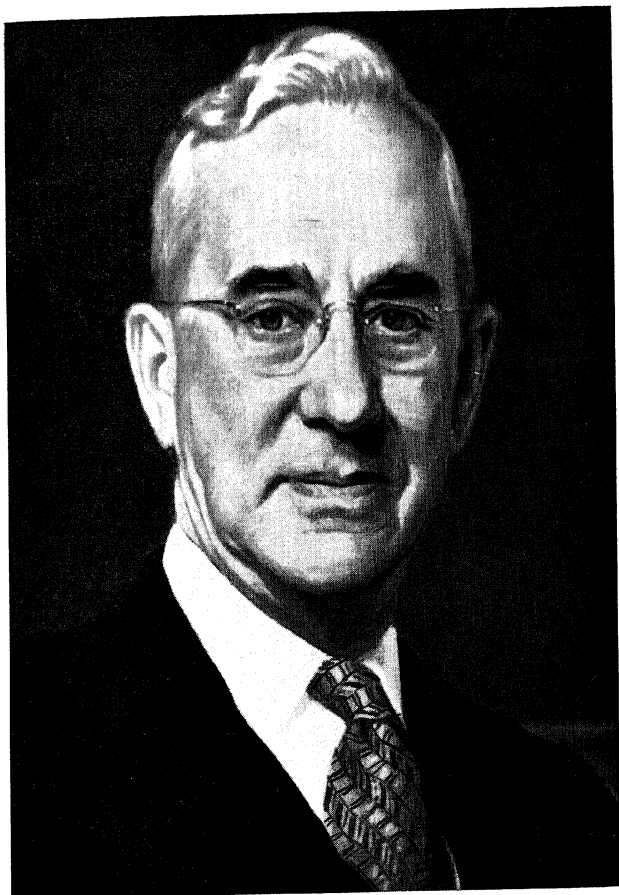
CITY OF WASHINGTON
PUBLISHED BY THE NATIONAL ACADEMY OF SCIENCES
1954

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James E. Blake

FRANCIS GILMAN BLAKE

1887-1952

BY JOHN RODMAN PAUL

Francis Gilman Blake was one of those unusual individuals who combined the qualities of a wise physician and an astute scientist. He was also the possessor of a kindly and understanding heart. He moved quietly through the professional environment of full-time university medicine, a medium for which he seems to have been made: medical laboratories, hospital wards, seminar and board rooms. Many of his associates admired him from a distance but never understood his taciturnity,—a few were so deeply inspired that they developed a lasting type of hero worship.

By far the greater part of his professional life was spent at Yale. Any graduate in medicine, who received his or her degree from the Yale University School of Medicine between the years of 1922 and 1952, or any House Officer who served on the medical service of the associated hospital¹ during that period knows for what he stood, both in the school and the hospital. Besides being Professor and Chairman of the Department of Internal Medicine, the responsibilities which he carried on his shoulders during that period included: Physician-in-Chief and Chairman of the Medical Board of the Grace-New Haven Community Hospital, and for seven years, Dean of the Medical School. A more detailed list of his appointments appears at the end of this article. But, although this list speaks for itself, it does not tell the whole story or indicate his real influence in the school in guiding its destiny, or his influence upon clinical medicine or clinical investigation in this country,—which is not to be measured in terms of multiple positions or tenure of office.

As to his origin, he was a true product of old New England on both sides of his family, his forebears having arrived in this country during the seventeenth century. Among this long line of New England families were a number of teachers, ministers and physicians who now lie sleeping in little country graveyards

¹ Designated as the New Haven Hospital up to 1946 and subsequently as the Grace-New Haven Community Hospital.

scattered throughout Maine and Massachusetts. His father seems to have deviated from this pattern somewhat and had become a mining engineer, interested in the coal and iron resources of Pennsylvania. Francis was born in the small Pennsylvania town of Mansfield Valley on February 22, 1887, the second of three boys. When he was three years old his father died. Most of his boyhood was spent either in Williamstown, Mass., or Brookline, Mass., where he had ample opportunity to develop at an early age a love of the out-of-doors. Most of his boyhood summers were spent at Camp Pasquaney in New Hampshire and when he "graduated" he returned as camp councillor and later as camp doctor. Indeed, Mr. "Ned" Wilson, the director of the camp, became almost a second father to him. It was not by accident that as a boy he roamed the woods and developed an enthusiasm for nature, particularly for birds; or that he took a year off between college and medical school to spend the winter in a log cabin in the Maine woods, for he was a born naturalist and he published, at the age of 15 (with his brother), his first scientific paper, on an ornithological subject. It appeared in *The Auk* in 1902.

During the year spent in the Maine woods he was getting ready, as it were, to go to medical school. He was not very rugged while at college, where he went under the name of "Bant", and I believe he derived a good deal of satisfaction from the thought that he might demonstrate his ability, as a camper, hunter and trapper, and to snowshoe his way through the forest in the dead of winter. But perhaps the most important aspect of this year in the woods was the task of tutoring a schoolboy by means of which he made enough money to enable him to study medicine. Three of them: "Bant" Blake, the recent Dartmouth College graduate; Horace Priest, an experienced Maine guide; and the schoolboy, took up residence together in a small log cabin deep in the woods. In a journal which he kept regularly at that time he wrote at the beginning of this adventure under the date of October 8, 1909:

"Horace and I set out early this morning. We walked along the tote road about a mile and then branched off down Bald

(Tyler) Mt. Brook, where Horace has a canoe. I stood up in the bow while Horace paddled me noiselessly down the brook. It was entrancing—right in the heart of the wilderness and beautiful beyond words—the slow dark water of the brook mirroring the spruce and fir and larches with exquisite perfection. Such solitude, such silence—only the almost noiseless dip of the paddle, and the occasional call of a downy or hairy woodpecker, or a flock of siskins twittering and buzzing. . . . It is good to be alive and well in the midst of these woods whose grandeur is awe inspiring. It lifts one up into the sixth heaven than which there is only one better.”

In the years immediately preceding, while at Dartmouth College, he had taken all the courses in biology and zoology that he could. His notebooks, now in the Yale Medical Library, bear witness as to how the science of living things had taken hold of him. He was never to forget biology and Dartmouth, nor did Dartmouth forget him; for he received an honorary Sc.D. from his alma mater in 1936.

In Boston both at the Harvard Medical School which he entered in 1909, and later, at the Peter Bent Brigham Hospital as a house officer, he spent altogether seven years, finishing up as resident in medicine, his opposite number in surgery being Dr. Elliott C. Cutler. Together they had planned to become Professor of Medicine and Professor of Surgery at Harvard;—a plan which did not misfire by a very wide margin.²

As to his teachers at Harvard, of all the members of the faculty whom I have heard him mention, Dr. Theobald Smith was spoken of more often than others, and always with admiration. Dr. Blake's early *medical* publications, which appeared while he was a house officer at the Brigham Hospital certainly reflect Theobald Smith's interests in the field of infectious disease and applied microbiology.

While he was at “the Brigham” he met and married in 1916, Dorothy P. Dewey of Springfield, Mass., who was a nurse in training there. It was the happiest of marriages, and no account

² Dr. Cutler eventually served as Moseley Professor of Surgery at Harvard.

of Francis Blake's life would be adequate without mention of his devotion to his family.³

Shortly after he left the Brigham Hospital, and at the urgent request of his wife, he began keeping a diary and this journal was maintained intermittently between the years of 1916 and 1921. It gives an intimate picture of his early professional life and in preparing this biography the diary has been drawn upon freely. In the diary are descriptions of the busy days of this crucial period in the young physician's life when, after years of semi-regimented life as a medical student, interne and hospital resident he doffs his white uniform, and decides what sort of a career in medicine he will make for himself,—a decision which usually comes later in life for the physician than for those in most other professions. With Francis Blake it was clear in his own mind and in the minds of his close advisors, Dr. Henry A. Christian and Dr. Francis W. Peabody, that he was headed for academic medicine; but could he afford it, and how to do it, and where, were questions he faced.

His first move after leaving "the Brigham" in September, 1916, was to accept a Fellowship⁴ at the hospital of the Rockefeller Institute and to move with his bride of three months to the "whirling metropolis" of New York City.

He was engrossed at this time with studies on cross immunity reactions between different varieties of pneumococci under the guidance of Drs. O. T. Avery and Rufus I. Cole. Three major

³ Their family consisted of three sons all of whom have chosen academic or scientific careers which reflects the atmosphere in which they grew up.

Francis Gilman Blake, Jr. born in 1917, attended both the College and Graduate School of Harvard University from which he earned a Ph.D. degree in Physics. During World War II he worked with the "Atomic Laboratory" at Los Alamos, New Mexico. He is now employed as Director of the Physics Laboratory at the California Research Corporation at Los Angeles, California.

William Dewey Blake, born in 1918, attended Dartmouth College and Harvard Medical School. After two years in the Army, he was associated with the Department of Physiology at the Yale University School of Medicine and is now Associate Professor of Physiology at the University of Oregon, Portland, Oregon.

John Ballard Blake, born in 1922, attended Yale College and the Graduate School of Harvard University where he is currently working for his Ph.D. in History.

⁴ Moseley Traveling Fellowship given by Harvard University.

pneumococcus types (I, II & III) had been identified by the Rockefeller group, and the Institute was buzzing with activity which concerned the significance of this finding. They were serious days too, for he recorded in his diary on February 8, 1917, "War seems inevitable and is probably but a matter of a few days."

Later that year (in June) he accepted a position as Assistant Professor of Medicine at the University of Minnesota and moved to Minneapolis. War had been declared in April, 1917. His first child (F. G. B., Jr.) was born that same month. Naturally he was concerned about entering the service and registered thoughts on this subject in November, 1917: "It would almost be too easy to go, and I feel for the present at least that my responsibility is at home".

This decision was reversed in January, 1918, when he applied for and accepted a commission as 1st Lieutenant in the Medical Reserve Corps and was off by early February to Fort Sam Houston, San Antonio, Texas. The Army with singular perspicacity had immediately picked him as one with special talents who could be put to work on a special assignment. This special assignment was with the "Pneumonia Commission," at that time stationed at Fort Sam Houston, whose members consisted of: Rufus I. Cole, W. G. MacCallum, A. R. Dochez, O. T. Avery, T. M. Rivers and four others, including himself. Of the five names which are mentioned, all of them either were or were to become members of the National Academy of Sciences.

Pneumonia in the U. S. Army Camps during World War I was a cause of great concern, and relatively a problem of much greater magnitude than it was in World War II. Among the most serious forms were: post-measles and post-influenzal bronchopneumonia. In the winter of 1917-18 post-measles bronchopneumonia was extremely prevalent in the training camps. The reason usually ascribed is that the crowding together of "susceptibles" was greater in 1917-18 than in 1942-45. In other words, in 1917 great numbers of boys from *rural* areas,—brought up in that pre-automobile era of isolated grade schools, who had not had the benefit of childhood exposure to measles, were suddenly gathered together in huge cantonments.

There, as unseasoned and non-immune recruits, they quickly picked up measles and other types of respiratory infections which often lead to the serious complication of pneumonia. From the clinical investigator's point of view this was a "pre-virus era" in which there was no exact knowledge as to what caused measles or influenza, or the common cold; and so the members of the Pneumonia Commission were forced to apply to their problem what microbiological talent and knowledge they had regarding acute respiratory disease, most of which lay in the field of bacteriology. The attempt to measure the degree to which bacteria such as pneumococci, *b. influenzae*, streptococci and staphylococci played a primary or a secondary rôle in initiating bronchopneumonia and lobar pneumonia was their difficult, almost impossible, task at that time.

That Francis Blake acquitted himself well in his Army assignment is borne out by the fact that he was promoted to be a captain within three months of his entry into the service. Soon afterwards, he was shifted to work with another commission studying pneumonia in the Army camps, whose activities were carried out at Fort Riley, Kansas, and Camp Pike, Arkansas. Its membership consisted of: Drs. E. L. Opie, H. S. Freeman, T. M. Rivers, J. C. Small and himself. Their work, written up as a monograph, was subsequently published in book form.⁵

In the autumn of 1918 and during the subsequent winter, the world had witnessed a *plague* the like of which had not been recorded for a generation before (or since). This was the pandemic of influenza. It struck hard in the Army camps of this country; the mortality there, as elsewhere, was appalling. Nothing in the way of prevention or treatment was effective. The patient with pandemic influenza in the early days of his illness was in a highly vulnerable stage, and very prone to pick up a bacterial infection caused by the pneumococcus (usually the heterogeneous "Type IV"), or *b. influenzae*, or streptococci or staphylococci, and often the pneumonia was caused by a mixture of these organisms. But whether the preceding in-

⁵ Opie, E. L., Blake, F. G., Small, J. C., and Rivers, T. M.: Epidemic Respiratory Disease. St. Louis, C. V. Mosby Co., 1921.

fluenza was *initiated* by these organisms, singly or severally, was a major concern with which the Pneumonia Commission struggled. The impression which this experience left on Francis Blake was never to be forgotten by him. It may have shaped his choice of a career. The pathogenesis and therapy of pneumonia remained for him a consuming interest during all of his professional life. It is reflected in his choice of a title, made by him and Gen. (then Col.) J. S. Simmons, 22 years later at the onset of World War II, for a board which was created to deal with epidemic diseases. Francis Blake was the first president of this board which was originally called: "The Board for the Control of Influenza and other Epidemic Diseases in the Army."

So deeply had he been stirred by this experience that unlike most young medical reserve officers, he did not leave the Army at once on the termination of the war in November, 1918. Instead he went to authorities at the Army Medical School in Washington and, as is recorded somewhat facetiously in his diary, he "brazenly approached Colonel Russell and told him if he would give me all the monkeys and laboratory space and assistance I wanted I would find out all that an eagerly waiting world wanted to know about pneumonia and influenza." Maj. Russell Cecil joined him in the project on which they worked for 20 months at the Army Medical School in Washington. Their results were published in a series of 10 papers which appeared in the *Journal of Experimental Medicine*. Nearly all of the work dealt with the experimental production of bacterial pneumonia in monkeys and ways and means of preventing its production. "Whether Cecil and I discovered all there is to be known about pneumonia or not," he wrote in his diary in November, 1920, "must be left to others to decide." Among the various society meetings before which he presented aspects of this work were the National Academy of Sciences at its meeting of November 1919 in New Haven; and the American Philosophical Society's meeting in Philadelphia in April 1920.

About this time he received an offer of a position as Associate in Medicine at the Hospital of the Rockefeller Institute in New York City which he "eagerly accepted." Here he was to pursue

experiments of a new type, for by now he had abandoned attempts to explain all there was to be known about pneumonia and influenza by working on *bacteria alone*, and entered the virus field. Experiments were begun with measles virus and together with his new found colleague and assistant, Dr. Trask, they proved conclusively that measles is due to a virus; that it can be transmitted experimentally to rhesus monkeys; and that the experimental disease is infective only in its earliest (pre-exanthem) stage. This line of experimentation was to continue. It directly led to subsequent work by Dr. Trask 10 years later in experiments at Yale on poliomyelitis virus infection in rhesus monkeys.

At the hospital of the Rockefeller Institute he was associated in the study of infectious disease with as brilliant and active a group of clinical investigators as had ever been gathered under one roof in this country. Most of them were old friends and included Rufus I. Cole, Oswald T. Avery, Homer F. Swift, Alfred E. Cohn, D. D. Van Slyke, and others. In the adjacent Institute building were Dr. Simon Flexner, Dr. Karl Landsteiner and a large number of others. It was a period of flood tide in the clinical investigation of infectious disease in this country and he was not alone in taking advantage of it. Indeed he was one of the most vigorous members of this group, endowed with two characteristics which made him stand out. First he had gained through experience a keen sense of the practical, clinical aspects of his problem; and second, he was imbued with an early appreciation of the *biology* of infectious disease. For the *nature* of infectious disease, and its *natural history* appealed to him as well as its control. He was a doctor first and a microbiologist second.

With this as a background, Francis Blake in 1921, at the age of 34 became Professor of Medicine at the Yale University School of Medicine in New Haven, Conn. He was one of a group selected at that time by Dean Winternitz to transform the Yale Medical School within less than a decade from a second-rate institution to one worthy of the University. It was at a time when the clinical faculties of a number of medical schools in this country, similarly situated in cities not much

larger or smaller than New Haven, were being reorganized, somewhat experimentally, on a full-time basis—Rochester and Vanderbilt were two of these other schools. At Yale the experiment worked from the very start. It exemplified how when the right man is chosen to fill the right position everybody benefits. However, in New Haven as elsewhere it was not all plain sailing. There were labor pains and after-pains. Within a very short time he had made himself indispensable at Yale, and so when, in June 1923, hardly a year and a half after he had arrived there, he received an offer from the University of Chicago to accept the Chair of Medicine and the deanship of their newly reorganized medical school, the Yale faculty were indeed perturbed. President James Rowland Angell wrote to him from his summer place, on July 4th, 1923, as follows:

"The compliment paid you by the invitation is very flattering and I congratulate you sincerely. I need hardly say, however, that if you are seriously tempted by the invitation I shall be greatly disturbed. I do not quite see how we could let you go without gravely disintegrating the plans we have cherished and without damaging most seriously the organization. We have started to build. On the other hand we must not play upon your loyalty to us in any unfair way. Anything that we can do to make you feel that the New Haven opportunities are as attractive,—or if possible more attractive than those at Chicago, I shall wish to attempt."

Dr. Blake's subsequent decision to remain in New Haven was received with acclaim. He remained as Professor of Medicine and Chairman of the Department of Internal Medicine at the Yale University School of Medicine for 30 years.

Success attended Francis Blake's efforts at Yale because he gathered at once into his department men of special calibre: Dr. W. S. Stadie and Dr. J. P. Peters (now both members of the National Academy) to develop the metabolic field, Dr. H. M. Marvin in cardiology, and his devoted follower Dr. J. D. Trask as his own special assistant. But success was also due to his singleness of purpose; confidence in his own capabilities; and his devotion to the concept of full-time medicine. His industry and enthusiasm carried the newly reorganized medical school forward. Few realized how hard he worked. Often he told

me that during the first ten years at Yale he rarely left his desk until midnight on at least four or five nights a week.

He had accepted the chair at Yale at a time when the concept of a strictly full-time professor of *clinical* medicine was new and regarded by some with suspicion. That a good doctor who became a professor of medicine, should renounce the privilege of carrying on a certain amount of private practice, notably consultation practice, and should accept instead a modest university professor's salary, was actually described in the early 1920's by some physicians as an "un-American" form of activity. Consequently, it is worthwhile perhaps to record here, two of Francis Blake's concepts about full-time clinical medicine which all of his local "extra-academic" colleagues and contemporaries do not seem to have appreciated. Primarily he certainly did not regard himself as a "contract physician" practicing "hospital medicine" for a stipend that could be measured in terms of money. Not that he did not need the money. He needed it desperately, for among other obligations he now had a family of three sons to raise and educate on a limited academic salary. But it was clear to him that his recompense lay in the opportunity which his position gave him, for teaching and carrying out *clinical investigation*, usually in collaboration with a junior member of his staff. Not only did it give him the opportunity to work intimately and enthusiastically with young men, but he was glad enough to raise money for *their* researches and then to leave them alone to find their own way. To have participated in this form of activity was his reward. It was also participation in the progress of medicine in this country. Obviously the ideal that he now set for himself was achieved more in his younger than in his older years. For the ever-increasing burden of administrative duties and extra-clinical responsibilities eventually swallowed up the precious time he had hoped to use for clinical investigation. But I think he counted himself lucky to have had 15 or 18 years of it.

Secondly, he had an extraordinarily clear vision as to what his functions in the medical school were. As Professor of Medicine, and later (1940-47) as Dean of the Medical School he was beset with requests for his services, or those of the

Medical School, to engage in various extra-academic consultations or community activities. His first consideration when asked to enlist his own services, or those of his department or those of the school, in such activities, was: "Is this a University function? If not, I shall not engage in it." For instance, he seldom engaged in out-of-town clinical consultations, although his services were sought over and over again. To him Dr. Abram Flexner's rugged tenets, which applied more during the 1920's perhaps than they do today, were a guide as to what a university should or should not be doing. It should not, according to Dr. Flexner, give society what it wants, but what it needs. Such needs were listed as four fold: i) the conservation of knowledge and ideas (as exemplified by the building up of university libraries or other collections); ii) the interpretation of knowledge and ideas (as exemplified by the encouragement of scholars and thinkers); iii) the search for truth (i.e., the gathering and integration of new data), and iv) the training of students.⁶

Let us consider him first in the role of a *teacher*. He certainly did not choose the easiest way here, namely instructing by *preaching*, but he followed the hard road instead, of instructing by *example*. He was convinced that if his behavior in the hospital wards, in the medical amphitheatre, or in the medical laboratory, was the best he was able to do, it might leave a more lasting and salutary impression on the student or house officer than any impressive pronouncements that he might make. This type of *apprentice teaching* reached fruition with his house staff and its hierarchial system of internes, assistant residents, and resident, each one coming a step closer each year to the Chief, and each member of the staff passing a little of his or her hero worship down the line, particularly to the third and fourth year students at the bottom. The example that he tried to set was primarily one of integrity in thought and behavior; of carefulness rather than brilliance. He seldom allowed himself to "think out loud." When the details of a given case had been presented to him he would often remain silent and with

⁶ Flexner, A., *Universities: American, English, German*. Oxford Univ. Press, New York, 1930, p. 6.

pursed lips proceed to examine the patient, then make his way over to the X-ray department to see the films, then down to the laboratory to look at the blood smears or the bacteriological findings; all this with his group of "apprentices" around him, and all this to see for himself, and weigh the evidence before his diagnostic decision was made. His action seemed to be in keeping with Wordsworth's lines that:

"Wisdom is oftentimes nearer when we stoop than when we soar."

These attributes have been clearly expressed by Dr. T. Francis, Jr. of Ann Arbor, Michigan, who gave one of three short addresses at a meeting organized to pay tribute to the memory of Francis Blake. It was held at the Yale Medical School five months after Dr. Blake's death.⁷ Tommy Francis as one of Dr. Blake's first students and house officers chose on that occasion to discuss his former chief as a *teacher*, pointing out primarily that:

"It is doubtful whether a man in any other calling can mould the thoughts and call forth so much endeavor from his students so completely and so enduringly as in that of the teacher-physician."

Dr. Francis then gave his own impression as a medical student in one of the early classes which came under the influence of the new Professor of Medicine at Yale in the 1920's.

"To us as undergraduates, Doctor Blake constantly brought the impression that we were participating in the march of medicine. At times it seemed he had cultivated what Osler called 'The Art of Detachment' to a high degree but on teaching rounds there was friendliness and encouragement, a willingness to discuss the perplexities, so that the sessions were anticipated eagerly as only too short group activities of enlightenment rather than squirming ordeals of exposed ignorance. He was authority, but did not use its voice; the why's and the how's were the theme."

⁷ This meeting was held in the Historical Library of the Yale University School of Medicine on Sunday, June 15, 1952. The two other speakers were: Dr. Stanhope Bayne-Jones of New York City and Dr. J. P. Peters of New Haven, Connecticut. See, *Yale Journal of Biology and Medicine*, 24: 569 (June, 1952).

As a *clinician* his great asset lay in the field of diagnosis. He was the ideal consultant. Careful, canny, astute and solid as a cedar post. He could sense what was wrong with a patient over and over again where others had failed. No one derived more pleasure from making a correct diagnosis, and the expression which he used to assume under these circumstances, was one of joy and triumph.

In the care of his patients he was chary with words, cautious with the use of any but specific drugs with constant warnings to his assistants about the dangers of unnecessary drug therapy which might result in "meddlesome treatment." But he was also a past master in the use of *specific* therapy having lived through and contributed materially to two eras in the treatment of infectious disease: the era of *antiserum*, and of *chemotherapy* or *antibiotic* therapy. The writer will not soon forget Francis Blake's excitement in the late 1930's during the early days of the use of sulfonamides, nor his indefatigable efforts to test their efficiency and measure the adequate dosage, to which his bibliography during that period bears witness. Nor will he forget seeing him one afternoon in June 1941, in earnest conversation with Dr. Florey (later to become Sir Howard) during the latter's visit from England to New Haven. Six months later Dr. Blake was to administer one of the first effective doses of penicillin given to a severely ill patient in this country. Nor will the writer forget being Dr. Blake's patient during an illness which kept him in bed at home for four weeks. Dr. Blake never missed a day visiting his patient during that period.

As a *clinical investigator* he was in his real element, having been drawn as any true medical biologist might into the clinical applications of microbiology and the study of infectious disease. It was a field which was to become in large measure transformed during his lifetime—and in this transformation he was to play no small part.

Mention has already been made of his special and particular interest in acute respiratory disease, notably influenza and pneumonia, but it was not confined to this, as can be seen by a glance at his bibliography. He turned his attention sequentially

to several special projects which may be reviewed in turn as:

i) Immunological reactions in infectious disease and their meaning or significance.

ii) The production of pneumonia experimentally,—and ways and means of preventing it.

iii) The virus etiology of measles, which was demonstrated in a classic series of experiments carried out on monkeys at the Rockefeller Institute in 1920-21 in collaboration with his junior colleague the late James D. Trask. The solidarity of the measles research team of Blake and Trask was such that Dr. Trask said when Dr. Blake was invited in 1921 to become Professor of Medicine at Yale, there never was a question in his own mind but that he would go too, even if he had to go as a technician. To remind Dr. Blake of these crucial and successful experiments two pictures of rhesus monkeys spotted with the rash of measles hung above his laboratory desk for at least 30 years.

iv) In the early 1920's, studies on scarlet fever were carried out by Blake and Trask in the isolation wards of the New Haven Hospital. They were the logical application to clinical medicine of Dochez's discovery that certain special strains of hemolytic streptococcus were the responsible agents in causing scarlet fever and these same strains of streptococcus produced an exotoxin, and, in the course of an infection, a demonstrable toxemia which might be treated successfully by scarlatinal anti-toxin. Dr. Dochez had turned to Dr. Blake, his friend and former colleague of the pneumonia commission. He knew of Blake's ability as a clinical investigator, and also that at the New Haven Hospital there was an infectious disease pavilion, as part of the general hospital, where scarlet fever patients were being treated within a few steps of Dr. Blake's laboratory.

The effectiveness of anti-scarlatinal serum as a therapeutic agent in scarlet fever was demonstrated by the team of Blake and Trask quite dramatically and the results were widely hailed in the lay press, more perhaps than in medical literature. The achievement did not receive the recognition it deserved perhaps because the severity of scarlet fever cases in this country seemed to decline in the 1930's and what was formerly a severe

disease with an appreciable mortality became a milder type of illness, as mild perhaps as the serum disease which often followed in some of the patients treated with anti-scarlatinal serum.

v) The possibility of the use of pneumothorax in the treatment of acute pneumonia.

vi) Chemotherapeutic agents and antibiotics with special reference to their effective doses, the duration of treatment and the dangers. At least 27 papers listed in his bibliography deal with these subjects.

In the autumn of 1943 during World War II, as President of the Army Epidemiological Board, he accompanied as director, a team of investigators which went to New Guinea, while it was still technically in the combat zone, to study scrub typhus (or tsutsugamushi disease). This was an important cause of serious illness among troops in action in the South Pacific and American scientists had very little first-hand knowledge at that time about the disease, its vectors and animal reservoirs.

This chance to visit New Guinea came at a time when he was overwhelmed with teaching and administrative responsibilities, both at home and in Washington. Actually it was a welcome break, for a letter written from New Guinea by Dr. Blake tells of his great pleasure in being able to spend several "quiet" weeks working all day in a special ward of a field hospital. He had to travel far in the South Pacific during war time to find this opportunity. He returned to New Haven with a wealth of new and important data on scrub typhus and a wonderful collection of butterflies from New Guinea, but he also had the bad luck to acquire tertian malaria from which he suffered recurrent attacks during the subsequent two years.

As an *administrator* he worked with dispatch and with no fuss. Seldom did he let administrative details keep him at his desk after 10:00 a.m. for he was due on the hospital wards at that time,—even when he was Dean of the Medical School. He had accepted the deanship of the School of Medicine under pressure in May, 1940 and at first as a temporary and emergency measure. The task of jointly administering the Department of Internal Medicine and also the whole medical school—(both full-time assignments in themselves) would seem to be an im-

possible one. The seriousness of the world situation at that time with World War II in full blast in Europe meant troublous days ahead for everybody. He knew there was to be rough sledding in the medical school which he faced with stern resolution.

His recreations were many in his younger days but had become less so in his later years. He maintained a love for the out-of-doors and natural history, and with his family spent most of the summers, prior to 1941, at their small cottage known as "Pebble Hedges" at Newfound Lake, N. H. He always enjoyed his membership in dinner clubs of which he belonged to several. He maintained an interest in stamp collecting all his life. Most of his later recreations were of a type that he could enjoy individually or with his family. He enjoyed travel to interesting and far places and during the next to last year of his life he and Mrs. Blake went round the world, a trip which was made as a result of an invitation received from the Australian Post-Graduate Medical Association to lecture in Australia.

This account would be inadequate without mention of Francis Blake's long record of service to his country. Here was one kind of extra-academic activity that he did not shun; perhaps it may have later become part of his philosophy of "teaching by example." Serving for 29 months as a Medical Officer in the Army in World War I he got to know the ways of the Army Medical Department and of Washington, where he later became very much at home. During the 1930's he was tireless in his work for the National Research Council and it was at that time that it became evident to this and other Washington agencies that here was a man of wise counsel. From 1945 the Surgeon General's Office of the Army, the National Research Council, the U. S. Public Health Service and the Office of Research and Development in the Army, turned to him more and more. But his greatest achievement in Washington was the organization and direction of the Army Epidemiological Board of which he was the first President—an office that he held for six years. The concept of this semi-military organization which utilized

but did not exploit university personnel was hatched in 1940 jointly by Gen. (then Col.) J. S. Simmons and Francis Blake.

It proved to be an effective and closely knit organization, based on the fact that it was not an advisory board *per se* but a working group equipped with contacts to carry out both basic and applied investigations in the field. It brought him in intimate touch with the great majority of medical scientists working on the subject of infectious disease throughout the entire country. The citation with which he was honored when he received for this achievement the Medal for Merit in January, 1946, is not a series of overstatements. It is singularly accurate.⁸

How one man could work so quietly and effectively over the years, how he could possess so many different capabilities—the research worker and the university administrator, the clinician, the teacher, the wise committeeman, and yet do well in all these fields, is a feature which caused those who knew him well to revere and well-nigh worship. But his labors told on him in his later years.

His death at the age of 64 came swiftly, for early in January 1952, only fourteen days after he had relinquished his duties

⁸ "Francis Gilman Blake, A.B., M.A., M.D., Sc.D., eminent physician and scientific investigator, leader in curative and preventive medicine, wise and able administrator, devoted servant of the health of the Armed Forces, for exceptionally meritorious conduct in the performance of outstanding services as Consultant to the Secretary of War, and President of the Army Epidemiological Board. Through his organization and direction of the Army Epidemiological Board since its establishment by the Secretary of War in January 1941, Dr. Blake has guided investigations, policies, and measures which have safeguarded the health of troops. He has directed research and the applications of research which have resulted in decrease of infectious diseases at Army posts and stations in this country and overseas and which have led to development of new protective measures. He has administered the Army Epidemiological Board as a means for preparation in advance of the outbreak of the war and as an effective weapon to combat communicable diseases during the war. In addition to his constant advisory assistance and supervision of the activities of the ten Commissions under the Army Epidemiological Board he has contributed benefits by his own personal participation in field work, under campaign conditions, to the understanding and control of scrub typhus fever, one of the most serious hazards to the health of troops in the Southwest Pacific Area. In his capacity as trusted adviser on the health of the Army and as leader in investigation and control of influenza and other epidemic diseases in the Army, Dr. Blake has rendered courageous and exceptionally meritorious service to the nation."

as Sterling Professor of Medicine at Yale and had moved his residence from New Haven to Washington, he suffered from a severe attack of coronary disease,—his second within a period of four months. He died on February 1 in the Walter Reed Hospital, Washington, D. C.

As mentioned earlier, a memorial meeting was held in his memory at New Haven in June 1952. At this same time an exhibit of his life and activities was presented in the Historical Library of the Yale University School of Medicine. To those who attended on that Sunday afternoon it was apparent that his quiet influence had penetrated into the hearts of many present and also had left its mark throughout the length and breadth of this country.

CURRICULUM VITAE

- 1887 Born (February 22), Mansfield Valley, Pennsylvania.
- 1908 A.B., Dartmouth College.
- 1913 M.D., Harvard Medical School.
- 1913-16 Successively: Medical Interne, Assistant Resident, and Resident, Peter Bent Brigham Hospital, Boston, Massachusetts.
- 1916-17 Moseley Traveling Fellow, Harvard University.
- 1917-19 Assistant Professor of Medicine, University of Minnesota Medical School.
- 1918-19 Served on active duty (during World War I) as 1st Lieutenant, Captain, Major, Medical Reserve Corps, U. S. Army.
- 1919-20 Associate in Medicine, Hospital of the Rockefeller Institute for Medical Research, New York.
- 1920-21 Associate Member, Rockefeller Institute for Medical Research, New York.
- 1921-52 John Slade Ely Professor of Medicine (1921-27), Yale University School of Medicine. Sterling Professor of Medicine, 1927-1952.
- 1921-51 Chairman of the Department of Internal Medicine, Yale University School of Medicine.
- 1921-51 Physician-in-Chief, New Haven Hospital (and later,

- 1946-1951) the Grace-New Haven Community Hospital, University Service.
- 1921-51 Physician-in-Chief, New Haven Dispensary.
- 1921 M.A. (Honorary), Yale University.
- 1924-35 Member of the Board of Scientific Directors, Rockefeller Institute for Medical Research.
- 1925-36 Member, Division of Medical Sciences, National Research Council (Chairman of the Division for the term 1933-36).
- 1928-51 Chairman, Medical Board of the New Haven Hospital, and later (1946-51) the Grace-New Haven Community Hospital.
- 1931 President, American Society for Clinical Investigation.
- 1932-33 Member, Executive Council, Association of American Medical Colleges.
- 1934-52 Associate Fellow of Silliman College.
- 1935 President, American Association of Immunologists.
- 1936-46 Chairman, Medical Fellowship Board, National Research Council.
- 1936 Sc.D. (Honorary), Dartmouth College.
- 1938 Chairman of the Section on Medicine, American Medical Association.
- 1939-47 Regent, American College of Physicians.
- 1940-41 Acting Dean, Yale University School of Medicine.
- 1940-52 Member, Committee on Chemotherapeutic and other Agents, National Research Council (Committee on Chemotherapy, 1946-52).
- 1941-47 Dean, Yale University School of Medicine.
- 1941-46 Consultant to the Secretary of War and President of the Board for the Investigation and Control of Influenza and other Epidemic Diseases in the Army, War Department, Preventive Medicine Service, Office of the Surgeon General, U. S. Army; known from 1946 to 1949 as the Army Epidemiological Board.
- 1943 During World War II, on expedition to New Guinea to study scrub typhus fever.
- 1943-47 Special Consultant to the Committee on Medical Research, National Research Council.

- 1943-46 Member, Subcommittee on Coordination of Malaria Studies, National Research Council.
- 1945-50 Chairman, Advisory Council, Life Insurance Medical Research Fund.
- 1945 Received Charles V. Chapin Memorial Award from the City of Providence, Rhode Island.
- 1945 Awarded United States of America Typhus Commission Medal.
- 1946 Awarded United States of America Medal for Merit, the highest civilian honor.
- 1946-52 Member, Army Epidemiological Board, known since 1949 as the Armed Forces Epidemiological Board.
- 1946 Vice-President and Chairman, Section on Medicine, American Association for the Advancement of Science.
- 1946-48 Member, Advisory Board on Health Services, American Red Cross.
- 1947 Elected to National Academy of Sciences.
- 1947-52 Member, Committee on Medicine, National Research Council.
- 1948 Vice-President, American College of Physicians.
- 1948 Elected Fellow, American Academy of Arts and Sciences.
- 1948-51 Member, National Advisory Health Council, U. S. Public Health Service.
- 1948-51 Chairman Committee on Medical Sciences, Research and Development Board, National Military Establishment.
- 1949 Elected Member, American Philosophical Society.
- 1948-49 President, Association of American Physicians.
- 1950 Participated in giving lectures in Australia under the Australian Postgraduate Federation in Medicine.
- 1952 Technical Director of Research, Medical Research and Development Board, Office of the Surgeon General, Department of the U. S. Army.
- 1952 Died February 1 in Washington, D. C.

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

- Abstr. Bact.=Bacteriological Abstracts
 Am. J. Hyg.=American Journal of Hygiene
 Am. J. M.=American Journal of Medicine
 Am. J. M. Sc.=American Journal of the Medical Sciences
 Am. J. Pub. Health=American Journal of Public Health
 Ann. Int. M.=Annals of Internal Medicine
 Ann. Otol. Rhinol. Laryn.=Annals of Otology, Rhinology and Laryngology
 Arch. Int. M.=Archives of Internal Medicine
 Arch. Pediat.=Archives of Pediatrics
 Boston M. & S. J.=Boston Medical and Surgical Journal
 Bull. New Haven Dept. Health=Bulletin New Haven Department of Health
 Bull. N. Y. Acad. M.=Bulletin of the New York Academy of Medicine
 Constructive M.=Constructive Medicine
 Fed. Proc.=Federation Proceedings
 Internat. Clin.=International Clinics
 J. Am. M. Ass.=Journal of the American Medical Association
 J. Ass. Am. M. Coll.=Journal of the Association of American Medical Colleges
 J. Bact.=Journal of Bacteriology
 J. Clin. Invest.=Journal of Clinical Investigation
 J. Conn. M. Soc.=Journal of the Connecticut Medical Society
 J. Exp. M.=Journal of Experimental Medicine
 J. Maine M. Ass.=Journal of the Maine Medical Association
 J. M. Res.=Journal of Medical Research
 N. England J. M.=New England Journal of Medicine
 N. Y. State J. M.=New York State Journal of Medicine
 Proc. Conn. M. Soc.=Proceedings of the Connecticut Medical Society
 Proc. Conn. Pub. Health Ass.=Proceedings of the Connecticut Public Health Association
 Proc. 3d Internat. Congr. Microbiol.=Proceedings of the Third International Congress for Microbiology
 Pub. Méd.=Publicações Médicas
 R. I. M. J.=Rhode Island Medical Journal
 Tr. Ass. Am. Phys.=Transactions of the Association of American Physicians
 Tr. Coll. Phys. Phila.=Transactions of the College of Physicians of Philadelphia
 Tr. Kansas City. Acad. M.=Transactions of the Kansas City Academy of Medicine
 Yale J. Biol. & M.=Yale Journal of Biology and Medicine

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Geno Dunn

GANO SILLICK DUNN

1870-1953

BY VANNEVAR BUSH

Gano Dunn was born in Yorkville, New York, October 18, 1870, the son of N. Gano Dunn and Amelia Sillick Dunn. His grandfather, Nathaniel Dunn, a school teacher and inventor, who attended Bowdoin College with Longfellow and Hawthorne, probably stimulated the younger Gano's bent for construction and engineering.

Dunn's father died before Gano had finished his education; and at the age of fifteen he began to work for the Western Union Telegraph Company, as an operator, in order to continue his schooling at the College of the City of New York. It was while he was still attending City College that Dunn had the extraordinary experience of visiting Thomas A. Edison in his laboratory. He later told of this experience when he received the Edison Medal for 1937, "Out of an almost infinite kindness for young men who were struggling," he said, "Mr. Edison received me in the midst of some laboratory work he was doing in the coating of laminated armature plates. Seeming to be interested in the questions I asked him, he drew me out in turn, and spent an hour personally showing me over his lamp works. . . . At the end of the visit, he offered me a job." Dunn did not accept the job, and Edison later admitted that Dunn had done the right thing in staying on to complete his college course.

In 1889 Dunn received his B. S. degree from City College and was honored by election to Phi Beta Kappa. He then enrolled in the newly established postgraduate electrical engineering course at Columbia University under Francis B. Crocker and Michael Pupin, and in 1891 received the first degree in electrical engineering ever given by an American university. Pupin later said that Dunn was the most versatile and gifted of all his students, and Crocker thought so highly of him that in 1891 he took him on first as an apprentice in his Crocker-Wheeler Electric Company and subsequently promoted him to assistant engineer, chief engineer, vice president, and director.

Dunn was only twenty-eight years old when he became vice president and chief engineer of Crocker-Wheeler. He was

placed in charge of the designing of electrical apparatus for both direct and alternating current, and he also supervised all of the scientific and technical work of the company. In developing his designs Dunn made very careful preliminary studies, investigating exhaustively all theoretical considerations, so that it was rarely necessary to make subsequent changes except, of course, when in the light of engineering progress designs for new machines had to be developed. And he had an eye for the aesthetic values in his designs.

While he was with Crocker-Wheeler he received the degree of Master of Science in 1897 from City College, submitting as his thesis "The Distribution of Electric Power in Factories." His interest in this subject redounded, no doubt, to the high reputation of Crocker-Wheeler in the field of electric motor drive. Among his specific contributions to the company's success were innumerable unpatented inventions and improvements in design and construction. He also registered many patents, which brought profit to the company. In 1911 he was offered the presidency of the firm but decided not to take it, preferring to move on from the field of manufacturing engineering to that of consulting and construction.

James Gilbert White, founder and head of the J. G. White and Company, was at the time looking for a vice president to take charge of engineering and construction for his company and was so impressed with Dunn's work that he offered him the position. Dunn accepted and, after helping to organize the company, he became its first president in 1913 and held the position until his death on April 10, 1953. The J. G. White Engineering Corporation, now one of the oldest consulting and construction engineering firms in the country, built under Dunn's guidance vast projects all over the world for both public and private agencies. Among these projects in the United States were the first long-distance natural gas pipe line in California; the Lake Ontario Ordnance Works for the manufacture of TNT; the original Government aviation station at Langley Field, Virginia; the 60,000 kilowatt steam station at Muscle Shoals now operated by the TVA; the Naval Ordnance Plant in Louisville, Kentucky; and manufacturing plants in Syracuse for the production of marine turbines and radar equipment.

The company also built the United States Government Airport on the Island of Fernando do Noronha off the coast of Brazil, the United States Naval Oil Base at Pearl Harbor, and enormous sulphur-extraction plants and oil refineries; and it even renovated and redecorated the Metropolitan Opera House in New York with new stage and house lighting, modern switch-board controls, ventilating, and air conditioning. It carried out a program of constructing roads, bridges, and irrigation works for the republic of Haiti, for which Dunn was decorated with the Order of Honor and Merit of the republic of Haiti. It also constructed three large irrigation and power dams in Chile and five in Mexico, power plants in Colombia, the Chiriqui railroad for the republic of Panama, and a 20,000 kilowatt power plant to pump oil from under water off the shores of Lake Maracaibo in Venezuela.

In 1940 the National Association of Manufacturers most appropriately bestowed upon Dunn their Modern Pioneer Award, and in 1947 the Pan-American Society of the United States, of which he was an Honorary President, presented him with its Gold Insignia.

For the Radio Corporation of America the J. G. White Engineering Corporation, under Dunn's direction, built thirteen transoceanic radio stations. Early in his career, Dunn had attended Institutes of the Radio Corporation of America and had received a first-class commercial radio operator's license. This training was to serve him well in later years when in an emergency he was able to receive and relay an S.O.S. message for a ship that was in trouble in the Pacific Ocean. Dunn met David Sarnoff when the latter as chief inspector of the Marconi Company represented his company in connection with the erection of the first transatlantic radio tower. In 1938 Dunn became a Director of the Radio Corporation of America and Sarnoff, Chairman of the Board, said in connection with his appointment, ". . . I wanted him because more than any other man living, Dunn brings poetry into science and engineering. I can explain that best by saying that if I ask a good engineer to explain a new circuit of some sort, I get an accurate description in suitable technical terms. But if I ask Dunn to describe it, I get an explanation of the relationship of that circuit to other

devices, an estimate of its possible uses and a prophetic glimpse of the developments to which it's apt to lead." One of the last trips taken by Dunn just a month before his death was for the purpose of learning about RCA installations in California.

The greater part of Dunn's life was lived as a bachelor and as a widower. He was fifty years old when in 1920 he married Mrs. Julia Gardiner Gayley. Mrs. Dunn died in 1937.

Dunn was always generous in the devotion of his time and energy to the needs of Government.

Before the first World War he served as the power expert member of the War Department's Nitrate Commission, and in this capacity he made studies of the Tennessee River with reference to its suitability as a source of power for the manufacture of nitrates.

In 1919 he was appointed Chairman of an interdepartmental committee established by the State Department to investigate the possible disruption of communication with our Allies and our military forces in Europe that might result from the cutting of transoceanic telegraph cables. The committee made a thorough study of the problem and worked out procedures for effecting communication in the event of an emergency. Luckily, the emergency did not develop.

Dunn was active on a number of other Government committees. In 1923 he was appointed a member of the Visiting Committee of the Bureau of Standards and continued to serve on it for twenty-five years. The late President Roosevelt appointed him a member of his Science Advisory Board, 1932-1936. He was the United States delegate and member of the Executive Committee of the World Power Conference in 1936, a member of the President's Committee on Civil Service Improvement from 1939 to 1941, a member of the Patent Office Advisory Committee from 1939 to 1941, Chairman of the American Committee of the World Power Conference from 1946 to 1952, and one of the advisers of the Public Works Task Force of the Hoover Commission on Organization of the Executive Branch of the Government.

Dunn at first opposed the Government's policy of developing the Tennessee Valley Authority in competition with private utilities, and in the lawsuit to test the constitutionality of the

Tennessee Valley Act, his firm was engaged by the Commonwealth and Southern Corporation to give expert testimony against the Government's position. But in 1940 he reversed his position and strongly recommended increasing the power capacity of the Tennessee Valley Authority on the grounds that it was necessary for the national defense.

In January and February 1941, at the request of President Roosevelt, Dunn made an exhaustive survey of the capacity of the steel industry to determine whether it had adequate facilities to meet the combined requirements of the United States and British defense programs as well as the expanded demands for civilian uses. He was at the time senior consultant to the Production Division of the Office of Production Management, but in this instance he made his report directly to the President.

The study was requested by the President because of conflicting estimates of steel requirements for the next two years and of the ability of the industry to meet all demands placed upon it. This question was of such importance to the defense program and the national economy as a whole that the President called upon Dunn, as a qualified authority capable of presenting an impartial, factual study, to make a special report on the subject. In the course of his initial investigation, which was carried out over a period of six weeks, Dunn consulted with a great many economists and experts, both in government and in industry, and representatives of organized labor in the steel industry. His first report was made in February. But in view of the importance of steel capacity and the necessity of having an up-to-date picture of the situation, the President asked him to regard this report merely as the starting point of a continuing study. Dunn accepted the assignment and undertook to revise his statistics and conclusions periodically.

His first report was strongly criticized as too optimistic by some of the Government's economists; and in a second report, presented to the President in May 1941, Dunn revised his estimates radically and concluded that the steel producing capacity of the nation was far from adequate to meet the increasing military demands. He questioned, however, whether the available labor supply was sufficient to expand the industry and pointed to the curtailment of civilian steel consumption as

the only feasible way of meeting the situation.

Dunn participated in the affairs of New York State and City no less than in those of the nation. He served as a consultant in 1941 to the New York City Housing Authority. He was a member of Mayor LaGuardia's Business Advisory Committee, a member of Governor Dewey's Temporary Committee on the Need of a State University and a member of his Technological Advisory Committee, one of three engineers appointed by the City Planning Commission during Mayor O'Dwyer's administration to make a survey and prepare a report on "Selected Measures for the Partial Relief of Traffic Congestion in New York City," and a member of the New York State Committee on Technical Industrial Development.

Among his many public services, one which was perhaps the closest to his heart, as it was certainly one of his most continuous endeavors, was his association with The Cooper Union for the Advancement of Science and Art. In 1925 he was appointed one of the five trustees of The Union and ten years later became their president, in which capacity he continued to serve until his death. One of his first acts as president of the trustees was a survey of the Union's activities in the light of its founder's purposes. Under his direction the Engineering School became a leader in giving the social sciences and the humanities a place in the professional education of engineers, and the Arts School embarked on a program of art education as distinct from mere training in technical skill. Dunn guided the investment policies of the endowment and was instrumental in increasing its income. At the 90th Commencement exercises of The Cooper Union in 1950 he was awarded the Peter Cooper Medal with a citation that read in part, "These fellow New Yorkers, Peter Cooper and Gano Dunn, separated by almost a century in time, have achieved in their individual ways great distinction in the application of science to the practical problems of life. In the character of both men are combined innate kindness and great integrity with creative inquisitiveness and incisive thinking. And they both have devoted themselves to the furtherance of the American ideal of equal educational opportunity for all people of whatever race, creed, or color."

Dunn was a trustee of Barnard College from 1922 until his death and a member of the Visiting Committee of the Harvard Engineering School from 1935 to 1951.

Columbia University honored him with the degrees of Master of Science in 1914 and Doctor of Science in 1938 and with the Egleston Medal in 1939; Rutgers in 1938 and New York University in 1941 conferred upon him Honorary Doctor of Science degrees. In 1933 his Alma Mater, the College of the City of New York awarded him the Townsend Harris Medal and in 1947 gave him an Honorary Doctor of Science degree. Lehigh University granted him an Honorary Doctor of Engineering degree in 1942 and Bowdoin College an Honorary Doctor of Laws in 1947 as America's "Engineers' Engineer."

Dunn took great satisfaction in the work of the American Institute of Electrical Engineers, serving on its governing board as a manager and vice president and as president, 1911-1912. From 1913 to 1916 he was president of the United Engineering Societies, an organization which he helped to start, and on whose board he was a member for many years. He played a prominent part in the organization of the Engineering Foundation, doing much to help secure endowments and acting as its first chairman from 1915 to 1916. Honorary membership was accorded him by the Association of Iron and Steel Engineers in 1912, the American Society of Mechanical Engineers in 1944, the American Institute of Electrical Engineers in 1945, and the American Society of Civil Engineers in 1949. He was also a member of important engineering organizations abroad. He was elected a member of The Institution of Electrical Engineers of Great Britain in 1911 and was appointed its Honorary Secretary in the United States in 1922. In recognition of his outstanding contributions to the field of engineering, Dunn was awarded the Edison Medal for 1937 and the Hoover Medal for 1939.

In addition to his engineering associations he was a member of numerous scientific, cultural, and intellectual groups, including the Franklin Institute, the American Philosophical Society, the American Academy of Arts and Sciences, the New York Historical Society, the Optical Society of America, and the New York Zoological Society. He was a Fellow of the New York

Academy of Sciences, the Institute of Radio Engineers, the American Association for the Advancement of Science, the Royal Microscopical Society of London, and the New York Microscopical Society. Dunn also belonged to several distinguished social clubs, among them the Union, University, Century, Knickerbocker, Tuxedo, Engineers—all of New York City—and the Cosmos Club of Washington, D. C.

Dunn was elected to membership in the National Academy of Sciences in 1919. When the National Research Council was organized in 1916, he became its first vice chairman and subsequently served as chairman from 1923 to 1928. Some members may recall the address he delivered on April 28, 1924, as Chairman of the Building Committee when he turned over to the National Academy of Sciences and the National Research Council the beautiful building which now houses their activities.

Of all his talents, perhaps the most fruitful was his ability to inspire confidence in all with whom he had to deal. And in consequence of this talent he invariably found himself pushed forward to a position of leadership in every group or organization to which he belonged. To quote a *New York Times* editorial of April 14, 1953, Dunn was "an outstanding leader in his profession, a man of deep integrity and a fine example of a public-spirited citizen." Bancroft Gherardi in awarding him the Edison Medal said of him that, "Combined with straight thinking and with frankness, which many engineers possess, he had diplomatic abilities of no mean order."

Raymond Moley compared him to Francis Bacon, saying ". . . there is something about his influence that suggests the role of that man of universal learning in the court of Queen Elizabeth. There is the hint of the sorcerer about Dunn—not the sorcerer of Disney's *Fantasia*, but the Elizabethan master of subtle mysteries. In twentieth-century terms, Dunn is a man who might push back impeccable cuffs and, to amuse his dinner guests between courses, repair a lagging chronometer or whip together a complete radio set. More astonishing than even such bits of legerdemain are the color and flashing opulence of his knowledge. Explanations of atomic power, coaxial cables and the uses of manganese in steelmaking are the kind of intellectual fare he sets forth for his friends. His mind moves joy-

ously among the miracles of an age that has never grown tired of producing miracles and exploring the miraculous.”

He was especially zealous in promoting the idea that engineering is a social art and that engineers to be wholly effective must be conscious of all the social values of their time. He defined engineering as “the art of the economic applications of science to social purposes,” and in 1930 he declared in an address before the Alumni of Columbia University, “And if his [an engineer’s] training neglects the great human mirrors of history and languages, particularly his own language, if his mind and his heart are insensible to the great social forces, if he but feebly develops the subtle qualities of character that make for personality, his career as an engineer is limited, no matter how much science he knows.”

Many of the physical achievements of Gano Dunn will live for generations as a monument to his greatness. But the one that he probably valued above all others was his very great accomplishment in humanizing the art of engineering.

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

- Am. Soc. Mech. Eng. = American Society of Mechanical Engineers
 Assoc. Iron & Steel Electr. Eng. = Association of Iron and Steel Electrical Engineers
 Concrete and Constr. Eng. = Concrete and Constructional Engineering
 Electr. Eng. = Electrical Engineering
 J. Eng. Ed. = Journal of Engineering Education
 Mech. Eng. = Mechanical Engineering
 Proc. Am. Inst. Electr. Eng. = Proceedings of American Institute of Electrical Engineers
 Proc. N. Y. Electr. Soc. = Proceedings of New York Electrical Society
 Science Mon. = Science Monthly

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<i>Number</i>	<i>Date Issued</i>	<i>Title</i>
27,098	May 25, 1897	Frame for Dynamo.
493,375	March 14, 1893	Mechanical balancing of armatures of dynamos or motors.
515,755	March 6, 1894	Automatic brake for motors.
549,061	October 29, 1895	Speed control of constant current motors.
591,343	October 5, 1897	Indirect voltage regulation of dynamos.
591,344	October 5, 1897	Constant current regulation of dynamos.
591,345	October 5, 1897	Constant current regulation of dynamos.
601,871	April 5, 1898	Electromagnetic circuit breaker.
618,853	February 7, 1899	Brush holder for dynamo electric machines.
638,627	December 5, 1899	Multiple blade starting switch.
654,142	July 24, 1900	Brake.
662,375	November 20, 1900	Multiple voltage controller for motor operation.

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735,352	August 4, 1903	System of electrical distribution for multiple voltage.
736,587	August 18, 1903	System of multiple voltage supply for motors.
754,980	March 22, 1904	System of speed regulation for motor-driven machinery.
768,738	August 30, 1904	Motor generator frame.
783,999	February 28, 1905	Commutator brush for direct current dynamos.
784,000	February 28, 1905	Commutator brush for direct current dynamos.
792,762	June 20, 1905	Brush rigging for dynamos.
797,271	August 15, 1905	Switch for controlling motor speeds.
839,060	December 18, 1906	Machine for bending metal strips edgewise.
855,237	May 28, 1907	Belt tightening idler.
879,949	February 25, 1908	Coil retainer for dynamo electric machines.
893,228	July 14, 1908	Pole structure of dynamo to reduce vibrations.
918,425	April 13, 1909	Method of bending metal strips edgewise.
922,107	May 18, 1909	Brush rigging for dynamos.
1,006,370	October 17, 1911	Lubricating device for journal bearings.
1,013,753	January 2, 1912	Sheet-metal punchings for squirrel cage motor.
1,104,784	July 28, 1914	Dynamo electric machine frame.
1,104,785	July 28, 1914	Multiple motor control system.

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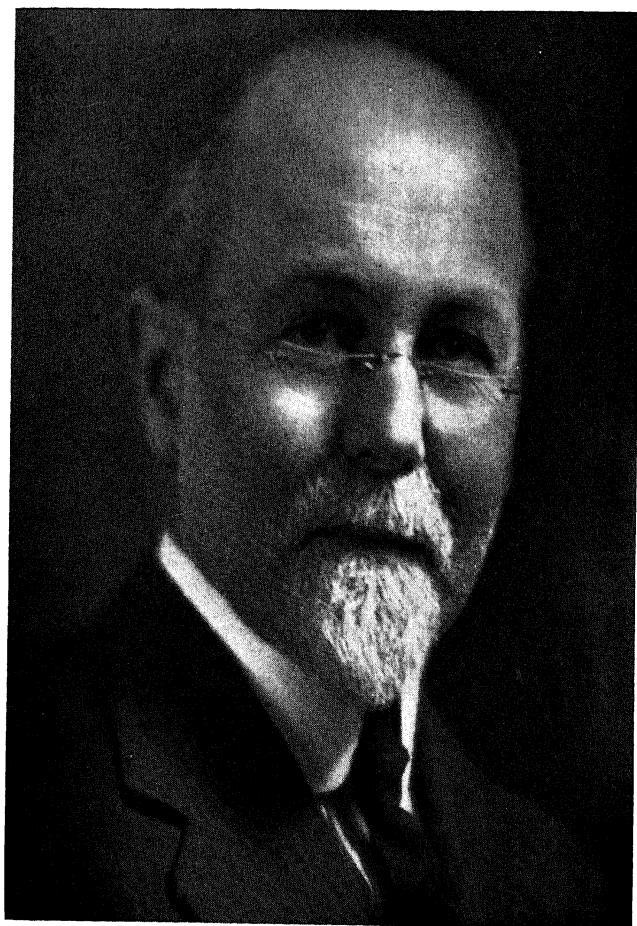
3,919	1904	Improvements in system of speed regulation for motor-driven machinery. (Corresponding to U. S. Patent no. 754,980)
9,874	1904	Improvements in electric-switches. (Corresponding to U. S. Patent no. 797,271)
12,400	1900	Brake. (Corresponding to U. S. Patent no. 654,142)
13,779	1904	Improvements in electrical distribution particularly applicable for controlling electric motors. (Corresponding to U. S. Patent no. 735,352)
23,296	1897	Indirect regulation of dynamo-electric machinery. (Corresponding to U. S. Patents no. 591,343, no. 591,344, no. 591,345)

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24,186	1899	Multiple blade starting switch. (Corresponding to U. S. Patent no. 638,627)
26,193	1906	Improvements in machines for winding metal strips edgewise. (Corresponding to U. S. Patent no. 839,060)

CANADA:

87,803	June 14, 1904	Improvements in system of speed regulation of electromotor-driven machinery. (Corresponding to U. S. Patent no. 754,980)
89,516	October 11, 1904	Improvement in electric switches. (Corresponding to U. S. Patent no. 797,271)
103,309	January 29, 1907	Machines for bending metal strips edgewise. (Corresponding to U. S. Patent no. 839,060)



Merritt L. Fernald

MERRITT LYNDON FERNALD

1873-1950

BY ELMER D. MERRILL

It is seldom that a boy of high school age really knows exactly what field he wishes to select for his life work. Yet with Fernald we have a positive case. As a boy he had developed such an intensive interest in botany, during and preceding his high school years in Orono, Maine, that at the age of seventeen he desired to make botany his life career. Considering the fact that at that time (1890), outside of the actual teaching of botany, there were not a half dozen full time positions in all of our institutions specifically created and supported to maintain the type of work in which this young man was interested, it is noteworthy that his first published paper of 1890 immediately attracted the attention of the one man in America who was in a position best to judge its author's promise. In 1890 such botanical positions as were available in the United States were essentially teaching ones, and then as now most botanical teachers, after taking care of their classes had little energy left to prosecute much research work. There were a very few exceptions here and there. The great development and diversification of botanical research in the United States came mostly within the present century. With this increase, research positions, as distinguished from merely teaching ones as such, were created all over the country. The result was a great proliferation in the plant sciences, including the development of entirely new disciplines such as genetics, cytology, cytogenetics, ecology (including much so-called ecology which was merely sugarcoated systematic botany) and other specialized fields, many of them never heard of at the end of the nineteenth century. With the development of the sometimes not too intelligent interest in the new subjects came a gradual decrease in the support of pure taxonomy. Thus by the middle of the present century the laboratory trained groups were in the ascendancy, and taxonomy, which is basic to all other disciplines in plant science, whether the devotees of these disciplines realize it or not, was in a very severe decline. This decline will inevitably con-

tinue for some years until a proper reassessment and evaluation is made, and a proper balance is reached.

In 1890 in the field of young Fernald's interest, a little work was being done in Washington, New York, Philadelphia, and in a few other centers in the country. For all practical purposes, however, the Gray Herbarium of Harvard University stood practically alone, yet at that time its assured income was very small. For the most part such botanical work as was then being accomplished in North America was not so much due to governmental and institutional policies and support, as to the fact that there were a few individuals who were keenly interested in field and herbarium work for its own sake. Their work was more often personally supported, rather than maintained by funds provided by the institutions with which some of them were connected. This was, in brief, the botanical situation in the United States when our account of M. L. Fernald opens.

The subject of this sketch was born in Orono, Maine, October 5, 1873, and died at Cambridge, Mass., September 22, 1950. His father, Merritt Caldwell Fernald, was the first and third President of the small Maine State College of Agriculture and Mechanic Arts at Orono (1869-71, and 1879-93), which became the University of Maine in 1898. His mother was Mary Lovejoy (Heyward) Fernald. Of the five children in the family two became well known scientists, one a chemist and the other a botanist. Young Fernald prepared for college at the Orono High School and entered the State College as a freshman in the fall of 1890. Fernald was not destined to continue in residence there for even his first year of college work. Because of his keenness as a budding field botanist, as evidenced in his early letters to Sereno Watson, and his first published botanical paper of 1890, Watson, then Director of the Gray Herbarium, became interested in him. On February 4, 1891, he wrote to young Fernald, expressing his appreciation of the intelligent interest that the latter showed in plant problems. While indicating that he had no idea as to what Fernald's plans for the future might be, or how far he was advanced in the educational field, he stated: "As a venture I would say that if a career as a botanist has attractions for you, there is an opportunity here for a young man who is

willing to begin at the bottom and work his way upward. . . . If such a position has any attraction I shall be glad to hear from you."

On February 7, Fernald's father expressed some surprise at Watson's offer, as his son was then only seventeen years old. The boy, however, had no doubts, for writing to Watson on the same day, he stated that the opportunity certainly did attract him, for: "I think the one thing which I was made for was a botanist, as from early childhood my inclinations have been in that line." A month later his father took him to Cambridge where he became a helper in the Gray Herbarium with an opportunity to continue his college career on a part time basis. His connection with that institution was to continue throughout his life, successively as Instructor, Assistant Professor, and Fisher Professor of Natural History, joining the Emeriti in 1947; but in the interim also serving as Curator of the Gray Herbarium, 1935-37, and as its Director for the next ten years. Thus it was his privilege to work continuously for sixty years, in a single institution and in a field that he had selected for a life career. This opportunity was an unusual one of which he took full advantage both as to the best interests of the institution itself and to his own remarkably productive career. He was incidentally an outstanding teacher, taking full part in the general teaching program of Harvard University, and attracting to the institution an unusually large number of graduate students who, not so much as subsidized individuals but rather on their own initiative, elected to matriculate at Harvard for graduate work in order to benefit from Fernald's vast knowledge of taxonomy and allied subjects. They made no mistake in selecting him as their major guide. The number of paid assistantships, fellowships and scholarships were few in botany, and the demand was great. His record in training future leaders in taxonomy is a remarkable one, and through them his name will continue to live on.

In September 1891 he entered the Lawrence Scientific School of Harvard University. He was graduated in 1897 magna cum laude with the degree of Bachelor of Science. During this period he worked half time at the Gray Herbarium, taking normally two academic courses each semester in Harvard College.

This was his only earned degree, although honors came to him in later years in the honorary D.C.L. from Acadia University in 1932, and D.Sc. from the University of Montreal in 1938.

His attitude towards formal advanced training, as expressed in his own words, with which some of us will agree is: "Practically my whole life (beginning in young school days, is a demonstration of my belief that natural scientists are born, not captured, and made in the laboratory—the place which usually deadens such interest) has been devoted to an intensive study of the higher plants (the flora), of temperate eastern North America, and an attempt to correlate distribution of the flora (and incidentally the fauna) with the geologic history of the area."

There was so much that claimed his attention when he received his B. S. degree in 1897 that he apparently did not consider it worth while to spend several years in graduate work to obtain the doctorate degree, the measuring stick by which individuals are judged by the directorates of so many institutions in this day and age, and considered to be the *sine qua non* for even a beginner. To Fernald, who knew what he wished to accomplish, and who had received the essential basic training, three years as a graduate student apparently impressed him as a waste of time. Undoubtedly he learned infinitely more botany as a part time assistant in the Gray Herbarium, 1891 to 1897, than he did in all of the formal courses he was required to take to complete the requirements for the basic degree, or would have learned as a full time graduate student. This is an excellent illustration of his independence, for he knew his objectives, and what he wished to accomplish. As a matter of fact, without the advanced degree, he proceeded infinitely farther than do the vast majority of the now great host who glory in the possession of the doctorate title. Few Americans in any field of plant science can match his accomplishments, and for the vast majority of those who earn the advanced degree, too often their published thesis is their only contribution to the literature of their profession.

Fernald was a voluminous writer, and his always critically prepared published contributions approximate eight hundred thirty or eight hundred ninety depending on how one evaluates titles and subtitles, as in the contributions from the Gray Herb-

arium series. Most of his work was on the flora of the region that has come to be known as the "Manual range," that is, those parts of the United States and Canada north of the southern boundary of Virginia, westward to approximately the position of the Mississippi River, and northeastward to the Maritime Provinces and Newfoundland. This, historically, with slight modifications at times, has been the range of Gray's Manual from its first edition in 1848, to the eighth or centennial edition, 1950. The latter is Fernald's work, and it was issued a few months before its author died.

To the preparation of this last edition of Gray's Manual he devoted a great deal of his time and energy during the past four decades of his life, first in preliminary work, and for the last fifteen to twenty years in the actual preparation of the text itself. He had been co-author, with B. L. Robinson, of the seventh edition of that standard work which appeared in 1908. Here his genius had manifested itself, for there is very little in common between the seventh and the preceding six editions, the Robinson-Fernald work, for all practical purposes being an entirely new book particularly in its arrangement and to a considerable degree in its content. All earlier editions had been largely compilations, for Gray was never a field botanist, and Robinson did no field work. In the last two editions is reflected the vast amount of critical field work accomplished by Fernald, with the assistance, in one form or another, of some 400 collaborators scattered over the entire area.

It seems worth while, here, to contrast the last three editions of this classical work in order to emphasize the significance of one of Fernald's major contributions to plant science. In 1890, in the sixth edition, 919 genera and 3,159 species were defined. Eighteen years later, for the same area, the corresponding figures were 1,001 genera and 4,079 species, with 806 entities subordinate to the species. Contrast these with the corresponding figures in the centennial edition of 1950, the personal field work of Fernald, for in this there are 1,133 genera, 5,523 species, and 2,817 entities subordinate to the species. This volume, Fernald's last major work, and the culminating one of his long botanical career, is by all odds, the most critical and searching

study in descriptive botany that has ever appeared on the flora of any part of North America. How time has justified Sereno Watson's judgment of a seventeen year old youth, whom he had not met when he offered him his first appointment in 1891, and how well did Fernald himself live up to his opportunities and thus vindicate his youthful belief that he was made to be a botanist!

It may seem strange to many productive systematists working on this or that little known flora, or engaged in monographic work, that Fernald should have selected an area which, a half century ago, was considered to be thoroughly well known from a botanical standpoint. Apparently even as early as 1890 Fernald, on the basis of his then very limited experience which had been restricted to a few localities in Maine, realized that much remained to be accomplished. At any rate he was not impressed with certain ideas that had become current earlier in the century that everything was known about the plants of the eastern United States. This idea dates back to Amos Eaton who in 1829 categorically stated that: "There is not, probably, 50 undescribed species of Phenogamous plants in the United States . . . perhaps not one species east of the Mississippi." With this, more or less prevalent, but utterly erroneous belief in mind, which in places persisted to the end of the century, compare the figures in the ultimate categories (species and minor forms) in the last three editions of Gray's Manual as above given. To a very large degree it was Fernald's own work that demonstrated the utter falsity of this strange idea.

With what is now happening in the botanical field, locally and elsewhere, one feels that no mere youth, no matter how promising he might be, and no matter what his personal interests were, could possibly be recognized by an appointment as a helper on the staff of a research institution at the early age of seventeen years and just as he was commencing his college career. It may be that figuratively Fernald was, in a botanical sense, "the last of the Mohicans," in that in 1950 there is no vestige left of the powerful group, beginning with Asa Gray in 1843, that built up and maintained the botanical prestige of Harvard University for just over a century. He left no real successor, which augurs ill

for the future of the types of investigations for which he stood, of which he was definitely the master, and on which his world-wide reputation rests.

It is suspected that when he penned the lines appearing in his Harvard class report in 1922: "consequently I am repeatedly forced to explain to the man in the street my failure to enter a money making profession . . . [because] I belong to that almost extinct species, the old-fashioned systematic botanist" he had some vague suspicion of some of the changes that were to occur within the next three decades culminating in the botanical debacle at Harvard University that immediately followed the implementation of the Irving W. Bailey report in 1946. Yet, had he such suspicions, he continued unswervingly to follow the phytogeographic interests which governed and largely shaped the course of his field and publishing activities. In all the years of his association with the Gray Herbarium its annual income was never sufficiently ample to cover more than the essential basic requirements. Strenuous exploring trips to various parts of the "Manual range" were apparently looked upon as luxuries perhaps to be financed as one would finance a vacation at a popular summer resort, yet one cannot exactly visualize Fernald being either a willing or a happy resort resident. These were the places he shunned, as the devil would holy water. Like others dependent on the comparatively small academic incomes prevalent in his earlier years he was obliged to seek grants from various sources to finance his field trips.

In spite of any suspicions that he may have harbored as to the real objectives of the new plan for botany at Harvard he accepted and supported it in good faith as did all other staff members of the nine separately endowed units involved. I do not for a moment suppose that the selection of the name "Fernald Drive" for one of the two streets driven through what was the oldest botanical garden in continuous existence in America appealed to him at all, when the garden was abandoned toward the end of his life. After all this was the first separately endowed unit of Harvard's once proud botanical empire, and the site had been the actual center of Fernald's life from the early part of 1891 to the day of his death nearly sixty years later. It is by no means im-

possible that the highly honored and very widely recognized name "Gray Herbarium" may disappear from the scene.

Outside of purely descriptive botany, Fernald's contributions loom large in other branches of plant science. He was admittedly one of the very keenest field men who ever operated in the region he selected, and for that matter, in the world at large. He made trip after trip in the early part of the present century to the then remote and not easily accessible parts of the Gaspé Peninsula, decades before that region became a Mecca for tourists, to Labrador and to Newfoundland; and these were arduous trips. In these long overlooked areas he was a pioneer botanical explorer. In later years, when further strenuous trips were no longer possible, he turned his attention to another strangely overlooked region, the coastal plain of Virginia and the discoveries he made there were as striking, or more striking, than were those he turned up of the less hospitable northern limits of the Manual range. How strange it is that other field botanists, closer to the scene, had consistently overlooked this coastal plain area, for it was the site of the first English speaking colony in North America. It took a Fernald to discover that the oldest settled region on our Atlantic seaboard was actually less known botanically nearly three hundred years after Jamestown was established, than any other part of our northeastern states.

His contributions to ecology are outstanding and put many of our professional ecologists to shame. His contributions to phytogeography are as eminent in this field as are those in descriptive botany and ecology. He entered the controversial field as to the extent of the Norsemen's knowledge of America, his "Notes on the Plants of Wineland the Good" *Rhodora* 12: 17-38, 1910, being an outstanding exposition of the possible fact, from the botanical evidence, that in contrast to the beliefs of the romanticists, these ancient visitors to North America may not have gotten south of Labrador. One doubts that forty years later Fernald would have insisted that all the conclusions he then reached were correct. The matter as to where these ancient visitors landed and attempted to establish a colony is still controversial for the romanticists must have their say. It is, however, an illustration of Fernald's broad interests, and like his other

mental excursions into controversial fields, clearly indicates that he was a master of numerous fields entirely outside of and some not even closely related to mere descriptive botany. This is the bane of many taxonomists in that they cannot rise above the level of pure descriptive work. They see so much that needs to be done, trivial or not, that they figuratively fail to see the forest because of the trees, and many of them do not rise above the level of trivialities. But not a Fernald.

Other targets were certain extremists among the glacial geologists who, apparently to a large degree on the basis of preconceived ideas, ardently supported the theory that most or all of the glaciated area in the northeastern United States and adjacent parts of Canada was entirely covered by a sheet of ice some thousands of feet thick during the Pleistocene glaciation. This was manifestly pontification. Fernald's contribution in the field of persistence of species of both plants and animals, clearly indicates that this hypothesis must be modified, for here and there were areas that escaped glaciation and in these areas various species of plants and animals did persist.

His conclusions were admirably summarized in his "Persistence of Plants in Unglaciated Areas of Boreal America" (*Mem. Amer. Acad. Sci.* 15: 239-342, 1925). Later he applied these same ideas to the plants of the Appalachian region and the Atlantic coastal plain. It has been stated by one authority that in reemphasizing the theory of persistence and in stimulating studies as to its implications, Fernald may have made the largest single contribution to the science of phytogeography since the time of Darwin. When he completed the task of seeing the eighth edition of Gray's manual through the press in 1949-50 he was planning to summarize all the vast amount of biological evidence that he had assembled appertaining to this situation for publication, but his sudden though not wholly unexpected death intervened. The master's voice is stilled and no one succeeds him in this particular field, even as at Harvard no one succeeds him as an authority on the taxonomy of the flora of eastern and northern North America.

A mere botanist, I take it, is not supposed to criticize the theories of specialists in extraneous fields, even if it may be pain-

fully evident that some of the theorists have clearly ignored Lord Acton's pithy saying: "The worst use of theory is to make man insensible to fact." Fernald reports that one positive glacial geologist who insisted on the thick continuous ice sheet idea, extending without a break from boreal America southward to Long Island and eastward to Newfoundland, on one occasion wrote to him (Fernald) begging him to desist in criticizing the theory because his findings were wrecking the complainant's reputation! In this field his phytogeographic and other contributions have forced the glacial geologists critically to reexamine the whole basis of theories which some had accepted as proved. Consider only the implications from the fact that there exists in Newfoundland an endemic species of caribou, strikingly different from the one that occurs on the North American continent—yet Newfoundland, according to some specialists, was completely and continuously covered by a thick sheet of ice during the Pleistocene glaciation. Naturally, this endemic mammal could not exist on snow and ice. But consider the scores of similar cases in the plant world, in the land snails, and in other groups of animals and the pattern clearly emerges as Fernald demonstrated. There were areas that escaped glaciation, this being a part of the nunatak theory that he so ably demonstrated; that is, areas here and there, large and small, that remained unglaciated in the vast sea of ice and hence able to support plant and animal life.

As a very keen critic, Fernald was preeminent. He was impatient regarding the published findings of incompetent and careless workers, who, apparently, are always with us. On the occasion of the presentation of the Leidy Medal to Fernald at the Academy of Natural Sciences of Philadelphia, in 1940, I stated the case thus: His trenchant criticism of the work of others in the general field covered by his activities, while not always pleasing to those criticized, assist in maintaining the standards of American botanical scholarship. On one occasion, when one of my former colleagues was requested to review a certain paper, which was far from being what it should have been, I heard him exclaim when he encountered a veritable howler: "Oh, for the pen of a Fernald!" Fernald's published papers on

botanical science exceed 700 [now over 800] in number. These always highly critical, carefully prepared, well written, and full of the results of very keen observation, set an unusually high standard within their field.

Fernald was not vindictive, and what he said about the work of this or that author, in general needed to be said. Even his last published review which appeared in the November, following his death, is a searching criticism of a recently published popular book on trees. It opens with this statement: "Everyone is interested in trees. The poet and the sentimental writer adore them; but we do not expect precision from them, and their ebullitions should not be looked upon either as science or factual. . . . But still trees are a tempting subject, both for those who admit that, for dramatic effect, they alter the facts, and by others who seem to be stating facts but who, obviously, have done altogether too little verification from the more exact and less spectacular sources which are available."

In another field, that of lexicography, if one be intrigued with a little gem of constructive criticism, one should read his little essay "Imagined Wisdom Without Understanding" (*Rhodora* 46: 312-315, 1944), which is a devastating critique of certain practices in the "beautifully printed and seemingly authoritative Dictionary of American English", by Craigie and Hulbert, issued by the University of Chicago Press in 1938. It is devastating. One hopes that the percentage of gross errors that he detected in the local names of plants considered may not be maintained for the other entries, for the work is generally accepted as authoritative in its field. There really should be some deep pink or dark red faces on the part of certain editorial staff members who perpetrated such gross errors in a field which they manifestly were not equipped to handle.

Fernald was a master of English composition and always gave very critical attention to the preparation of his manuscripts. It was his habit to pencil his first draft on large sheets of newspaper stock, and then proceed to revise and polish the original copy. In this he was very meticulous. The very many visitors who called at the Gray Herbarium during his periods of literary composition will all remember his habit of reading his copy to

them, expounding his reasons as he proceeded, often interspersing rather pointed comments of how obtuse this or that author was (not however included in his copy) and always revising and polishing his text as he proceeded. One simply could not escape until the end was reached. Nor was he adverse to accepting suggestions whereby this or that point might be emphasized.

It is a striking tribute to his unrivaled knowledge in special fields that those who may have been subjected to Fernaldian castigations have made no effective rejoinders. These literary castigations were, in general, only too well deserved, but, as noted above, they were not of the vindictive type. Yet human nature being what it is, his effectiveness in this field did not always endear him to those he criticized.

He will be remembered by those who knew him as an outstanding individual, a man who had opinions and who, when sure of his ground, did not hesitate to express them. He subordinated much of his life to the advancement of botanical interests. Even in his later years, after retirement, he worked long hours daily in the herbarium and library and continued his work at home in the evening; in spite of the fact that he had suffered from two mild attacks of coronary thrombosis, and that in the last years of his life his eyesight was very seriously impaired, operations on both eyes for cataract being required. He was always pungent, interesting, a teacher of keen insight, with a fine sense of humor, but always an individual whose standards of work were very high. He will be remembered by the numerous graduate students whom he trained and by the very wide circle of correspondents who depended upon his unsurpassed knowledge of the flora of eastern and boreal North America. His knowledge of the vast literature published in all languages appertaining to the flora of his special area and to the North Temperate Zone as a whole, was unrivaled.

When one considers the very broad field of plant science covered by Fernald (and let no doubting Thomas think for a moment that his interests were by any means confined to taxonomy and descriptive botany, fields which now may be subjects of derision by some individuals who should know better) his abso-

lute devotion to various aspects of the subject, and his subordination of his other activities to the advancement of the subject matter that intrigued him, one is reminded of certain entries in Linnaeus' *Critica Botanica* (1737). There is a definite similarity as between the Linnaean approach and that of Fernald. The latter admitted in his class report for 1922 that he was "attempting to attain and record as exact an understanding as possible of the natural flora of the region [Hudson Strait to the Great Lakes and Long Island] and the geological and geographic conditions of the past under which the plants (and with them the animals) reached their present habitats". He then as noted above referred to having at times had to apologize because he had failed to enter a money-making profession. To him, at least, money was not everything, and he preferred to remain an old-fashioned systematic botanist. He kept the faith, and in so doing attained a very high eminence in the field of plant science.

Linnaeus after discussing the significance of generic names perpetuating such individuals as Bauhin, Dorsten, Hernandez, Dillenius, Gronovius, Commelin and others, even including himself,¹ observes: "What can mortals desire more in this transient world of little moment than that a creditable memory of their names may reach posterity and live yet a few days more." He followed this with a remarkable statement which applies to Fernald and to many others who have disinterestedly labored throughout their lives in the field of taxonomy: "What pains, what research could be more tiring and laborious than botany, if it were not that enchantment of a strange will, which I myself cannot explain, often drove us in this direction, so that love of plants vanquishes love of ourselves. . . . Good God! When I muse upon the fate of botanists, upon my word I know not whether I shall call them wise or bereft of reason in their enthusiasm for plants. Every botanist himself knows how many laborious days and sleepless nights, how many hours it is as difficult to spare from other occupations, and what enormous sums he has sacrificed, merely with the intention of serving

¹ "*Linnaea* was named by the celebrated Gronovius and is a plant of Lapland, lowly, insignificant, disregarded, flowering but for a brief space—from Linnaeus who resembles it."

others. . . . Alas that so much toil should gain so humble a reward; and yet how welcome to the recipient such a reward should be!" The quoted passages are from Blair's translation of Hagberg's *Linnaeus* (1952).

Professor H. H. Bartlett had the fortunate experience of studying under Fernald. He successfully revived the *Asa Gray Bulletin* in 1952, after its demise in 1901 with eight volumes issued, 1893-1901. Its revival was under the auspices of the University of Michigan; this was, incidentally never a Harvard sponsored periodical. In his appreciation of Professor Fernald's work on Gray's *Manual* he discussed an advertising flyer of four pages prepared by Fernald (but anonymously published) distributed with the April and May numbers of *Rhodora* in 1902 (and probably in many sets discarded in binding, as was the case in the *Arnold Arboretum* set). Its title was: "Why Not Spend the Summer in the Maine Woods?" This was prepared for the then recently opened Bangor and Aroostook Railroad that a few years before had made northern Maine easily accessible. Bartlett stated: "Never before or since has there been such an advertisement, which should by all means be included in a bibliography of Fernald's writings." I agree and it has been included in the appended bibliography to this document. To be appreciated this small document must be read. Bartlett's summary is: "I know nothing in botanical literature with quite the flavor of this advertisement except Bartram's *Travels*. It would warm the cockles of any botanical heart."

I agree that there is much in this little document that suggests certain entries in Bartram's *Travels* that so greatly influenced the poetical imagery that appears in the works of Coleridge and Wordsworth as demonstrated by the late Professor J. L. Lowes in his "The Road to Xanadu", and also by other authors. The same flavor appears in Fernald's brief but most enthusiastic, in fact at times almost poetic, statements associated with this, that or the other binominal in stressing the botanical riches to be observed in the wilderness of northern Maine. Clearly Fernald felt at that time that everyone should be as keenly interested in this or that named species to be observed in the Maine woods as he was himself. This interest continued to the very end of his

life. I would add to Bartlett's comparison of the Fernaldian enthusiasms to those of John Bartram that similar comparisons could be made between various entries in the works of both authors to selected ones in Linnaeus' *Critica Botanica*.

This account of Professor Fernald is frankly an amplification of the one I prepared for the Yearbook of the American Philosophical Society, 287-295, in 1950. I met Fernald first in 1900, saw him rarely and for brief intervals for the next 35 years, and only became associated with him in administrative matters in 1935. Messrs. Pease, Raup and Rollins admirably summarized the outstanding aspects of his personality (*Harvard University Gazette* 46: 78. 1950) in these words:

"What Fernald's friends and even casual acquaintances will remember about him is not however, his official positions and honors nor even the bulk of works he produced, but the unforgettable character of the man. Tireless in labor, vigorous in expression, fearless and outspoken in controversy or criticism, he yet had a real appreciation and respect for honest work of others. He possessed an extraordinary capacity to stimulate in his associates, by suggestion and commendation—especially in students and in those not too set in their own ways and conceits—an enthusiasm for research and discovery."

Deliberately the majority of Fernald's reviews of the published work of others have been included although he would not have approved of this for when he supervised the preparation of the bibliography of his predecessor, Dr. B. L. Robinson, he forbade the inclusion of any reviews. My reason is that the Fernald's reviews were never perfunctory. In many cases he included really critical analyses, not always pleasing to the authors concerned. Here he clearly indicated his mastery of the situation, the fields covered being those to which he had assiduously and uninterruptedly devoted his full time for a period exceeding a half century of highly productive work. And sometimes these reviews appeared under very expressive titles such as the one mentioned above with the title: "Imagined Wisdom Without Understanding" in 1946. The volume, a reference book in the lexicon category that he justly and very severely criticized was only in small part botanical, but the review was utterly devastating.

I became involved in one of Fernald's pet fields during World War II when on one occasion he happened rather casually to mention the unpublished manuscript of the Kinsey-Fernald "Edible Wild Plants of Eastern North America". The original draft had been prepared during the course of World War I but when the copy was ready for the printer no publisher would accept the manuscript on the theory that with the close of the war there would be no demand for the book. I casually mentioned the text to a New York friend who happened to own a large printing plant. His response was immediate and to the effect that he would publish the book if I could get the manuscript ready on rather short notice. Dr. Fernald was then deeply involved in the completion of the text for the 1950 edition of Gray's Manual, and he did not welcome the task of bringing this almost forgotten manuscript on native edible wild plants up to date. Yet he took on the task and even added several species after testing them personally, such as one of our commonest garden weeds (*Galinsoga*) and another plant of American origin (*Erechtites*) now widely naturalized in Malaysia, which, with others I knew were extensively used for food in the Orient; I had been involved in the preparation of the first emergency food manual for the use of our armed forces operating in the southwestern Pacific region, for like Fernald in New England my basic knowledge of this particular subject had been built up over a period of twenty years in field work in the oriental tropics. This was a field in which he was thoroughly competent from very wide personal experience, for the text was not a mere compilation, but every species included in it had been tested as food by Fernald himself. In the early days of the New England Botanical Club when the organization was small and meetings were held at the homes of individual members, it was his delight to provide and serve this or that "unknown" food; and on one occasion when some coal-black buns appeared on the table they were looked upon askance until one of the members realized that the color of the buns was due to the presence of the small jet black seeds of a wild species of *Amaranthus* which was a very common plant on the city dump and in waste places in Cambridge. After that there was no color line for although it may

not now be generally known, the seeds (and even the tender growing leaves and the tips of the branches) of the amaranths are not only edible but provide excellent food. These *Amaranthus* plants were one of the most ancient sources of food to our primitive ancestors in both hemispheres.

The total number of published papers and individual volumes, and it is suspected that some have been overlooked, approximate eight hundred and thirty titles, but if it had been elected separately to list the individual titles, varying from one or two to as many as eight appearing in individual issues of *The Contributions from the Gray Herbarium* (1897 to 1949) the total would be about nine hundred. It is no wonder that some of our non-productive colleagues, have at times, accused this or that active and productive individual of having published too much! There are times when comparisons are odious.

Here is a case where, because of the many facets of his personality, it may well be said that when he was formed the mold was destroyed; there never can be another Fernald. Doctor A. S. Pease, who was intimately acquainted with him from long association from his student days throughout his future career as an educator, socially, in the herbarium, and on various long and rugged field trips, states that although Fernald never wore his heart upon his sleeve he had a deep respect for sincere moral character. Although scientists are sometimes accused of impersonal stolidity, the one of Fernald's sayings that he likes best to remember was in reply to a thoughtless youthful remark to the effect that a certain investigation, even if carefully pursued, could have only sentimental value. Fernald's response, with a good deal of feeling was: "This world would be a pretty poor place if there were no sentiment in it."

Merritt Lyndon Fernald kept the faith and carried the torch of his profession high. It is rather striking that his very last paper, published posthumously in 1951, should bear the title: "The Future of Systematic Botany". There is much in this short paper that is well worthy of critical consideration by the most extreme exponents of what has become to be known as the new systematics, and by the even more radical exponents of what may be known as the laboratory school where the major prob-

lems in the field of plant science are apparently to be solved by the application of the principles of plant physiology, genetics, and biological chemistry. Perhaps systematics was overdeveloped in the holding institution as a whole but it should have been remembered by the sponsors and supporters of the new plan that much of the endowment of the four units involved, and all the funds provided for construction purposes had been provided not by the University but by friends of this or that unit to support specific types of work that Asa Gray initiated in 1843. This field he developed until his death in 1888. Perhaps it is well that Fernald reached the end of his very effective and productive career before the existing great reversal in botanical objectives came. What has happened since his retirement, and particularly since his death in 1950 has been catastrophic to those types of botanical research that he believed in, of which he was the greatest living master in America and to which his entire lifework was devoted. The end is not yet, and a more balanced program may yet be developed before another threatened catastrophe happens.

I here quote from Prof. H. H. Bartlett, *Rhodora* 53: 48. 1951: "In botany Harvard's policy was then [1904], as it still remains, to belittle its own best achievements and to disregard its most valuable resources and traditions in building for a glorious new future. So the [Gray] Herbarium, then and subsequently, had the problem of finding in large part its own substance, with little or no encouragement from the top echelon". The same statement is true of seven of the eight existing separately endowed botanical units. But now dictation prevails from above, and all the units now rapidly decline in productiveness and in prestige.

For further details regarding Professor Fernald's career and accomplishments, see the several papers prepared by individuals much more intimately associated with him than I ever was. *Rhodora*, volume 53, No. 626, pp. 33-65 consists of a series of papers by Messrs. A. S. Pease, J. M. Fogg, Jr., H. H. Bartlett, Reed C. Rollins and Ludlow Griscom on Fernald's life, as a teacher, as a reviser of Gray's Manual, as a botanist, and as a field botanist. These are a remarkable series of tributes to the man.

Fernald was honored by election to various important scientific societies both at home and abroad, including the American Academy of Arts and Sciences, the National Academy of Sciences, and the American Philosophical Society, the Franklin Institute of Philadelphia and the Pennsylvania Horticultural Society. He was a supporting member of our important botanical societies. Abroad he was recognized by elections as a Foreign Member of the Linnaean Society, London; Royal Science Society, Uppsala; Société Linnéenne de Lyon, the Societas Phytogeographica Sueciana, Societas pro Fauna et Flora Fennica, and the Norske Videnskaps Akademi. He was a member of various local and national societies concerned with the plant sciences, serving a term as President of the New England Botanical Club (1911-1914); President, Botanical Society of America (1942); President of the American Society of Plant Taxonomists (1938); and Vice-President, American Association for the Advancement of Science (Section G, Botany, 1941). He was also recipient of the Leidy Gold Medal of the Academy of Natural Sciences, Philadelphia (1940), the Gold Medal of the Massachusetts Horticultural Society (1944), and the Marie-Victorin Medal awarded by the Foundation Marie-Victorin for outstanding services to botany in Canada (1949). He was associated with the editorial policies of *Rhodora*, the Journal of the New England Botanical Club from the year it was established (1899), and was its editor from 1924 to 1950. Prof. H. H. Bartlett describes it as "one of the most highly personalized of scientific journals, in an era in which most editors have deemed it scandalous to reveal any personality at all". Personality is a character that was Fernald's to a very high degree; and those who were associated with him as students, as colleagues or otherwise will always remember him, and appreciate him for what he was—one of our very greatest and best informed botanists in the fields he mastered and a very worthy successor of the greatest of them all in North America, Asa Gray.

Professor Fernald married Margaret Howard Grant, of Providence, April 5, 1907, who survives him. From this marriage there were three children, Katharine (Mrs. H. G. Lohnes),

Henry Grant, and Mary, of whom the first two survive. There are six grandchildren.

In the preparation of the following bibliography I am very greatly indebted to Dr. Fernald's daughter Katharine (Mrs. H. G. Lohnes), for a critical examination of the botanical literature involved (for the subject of this sketch did not maintain a complete set or even a partial list of his published papers); it is on Mrs. Lohnes' data that this bibliography is based. Mrs. Lazella Schwarten, librarian at the Arnold Arboretum, has prepared the final copy, checking references when desirable, and unifying the citations. Considering that Professor Fernald published in about thirty-five different periodicals, the work speaks for itself, even if the vast majority of the items appear in one periodical, *Rhodora*.

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

- Amherst Grad. Quart. = Amherst Graduate Quarterly
 Am. Jour. Bot. = American Journal of Botany
 Am. Jour. Sci. = American Journal of Science
 Ann. Assoc. Am. Geogr. = Annals of the Association of American Geographers
 Asa Gray Bull. = Asa Gray Bulletin
 Bot. Gaz. = Botanical Gazette
 Bot. Soc. Exch. Club British Isles = Botanical Society and Exchange Club of the British Isles
 Bot. Tidsk. = Botanisk Tidsskrift
 Bull. Am. Geogr. Soc. = Bulletin of American Geographical Society of New York
 Bull. Bklyn. Inst. = Bulletin, Brooklyn Institute of Arts and Sciences
 Bull. Geogr. Club Phila. = Bulletin of the Geographical Club of Philadelphia
 Bull. Harvard Club Boston = Bulletin of the Harvard Club of Boston
 Bull. Josselyn Bot. Soc. = Bulletin of the Josselyn Botanical Society of Maine
 Bull. Torrey Bot. Club = Bulletin of the Torrey Botanical Club
 Canada Field-Nat. = Canadian Field-Naturalist
 Canada Dept. Mines Victoria Mem. Mus. Mem. = Canada Department of Mines Victoria Memorial Museum Memoirs
 Chron. Bot. = Chronica Botanica
 Erythea = A Journal of Botany, West American and General
 Fifth Int. Bot. Congress, Report of Proc. = Fifth International Botanical Congress Report of Proceedings
 Garden & Forest = A Journal of Horticulture, Landscape Art, and Forestry
 Geogr. Rev. = Geographical Review
 Harvard Alumni Bull. = Harvard Alumni Bulletin
 Harvard Stud. Class. Philol. = Harvard Studies in Classical Philology
 Harvard Univ. Gaz. = Harvard University Gazette
 Jour. Am. Pharm. Assoc. = Journal of the American Pharmaceutical Association
 Jour. Arnold Arb. = Journal of the Arnold Arboretum
 Jour. Bot. = Journal of Botany British and Foreign
 Jour. Franklin Inst. = Journal of the Franklin Institute
 Leaflet West. Bot. = Leaflets of Western Botany
 Mem. Am. Acad. = Memoirs of the American Academy of Arts & Sciences
 Mem. Gray Herbarium = Memoirs of Gray Herbarium
 Nat. Acad. Sci. Biog. Mem. = National Academy of Sciences—Biographical Memoirs
 Nat. Geogr. Mag. = National Geographic Magazine

- North Am. Flora = North American Flora
 Off. Reg. Harvard Univ. = Official Register Harvard University
 Ottawa Nat. = Ottawa Naturalist
 Proc. Am. Acad. = Proceedings of the American Academy of Arts and Sciences
 Proc. Am. Phil. Soc. = Proceedings of the American Philosophical Society
 Proc. Boston Soc. Nat. Hist. = Proceedings of the Boston Society of Natural History
 Proc. Int. Congress Plant Sci. = Proceedings of the International Congress of Plant Science
 Proc. Portland Soc. Nat. Hist. = Proceedings of the Portland Society of Natural History
 Quart. Rev. Biol. = Quarterly Review of Biology
 Trans. Mass. Hort. Soc. = Transactions of the Massachusetts Horticultural Society
 Vt. Bot. Club Bull. = Vermont Botanical Club Bulletin
 William & Mary Lit. Mag. = William and Mary Literary Magazine
 Yrbk. Am. Philos. Soc. = Yearbook of the American Philosophical Society
 Zoe = A Biological Journal

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 Some annual halophytic *Asters* of the Maritime Province. *Rhodora* 16: 57-61.
 Three *Lupines* naturalized in eastern Canada and Newfoundland. *Rhodora* 16: 92-94.
 The narrow-leaved variety of *Salix pyrifolia*. *Rhodora* 16: 116.
 (With K. M. Wiegand) The genus *Ruppia* in eastern North America. *Rhodora* 16: 119-127.
 Some *Antennarias* of northeastern America. *Rhodora* 16: 129-134.
 (With G. B. Dorr & E. N. Forbush) The unique island of Mount Desert. *Nat. Geogr. Mag.* 26: 75-89.
 (With H. St. John) *Nymphaea variegata* or *N. americana*? *Rhodora* 16: 137-141.
 The American variations of *Stellaria borealis*. *Rhodora* 16: 144-151.
 The variations of *Ranunculus cymbalaria*. *Rhodora* 16: 160-162.
 The West Virginian variety of *Polygonum cilinode*. *Rhodora* 16: 165, 166.
 The glabrous-leaved sweet gale. *Rhodora* 16: 167.
 Some willows of Boreal America. *Rhodora* 16: 169-179.
 (With H. St. John) The varieties of *Hieracium scabrum*. *Rhodora* 16: 181-183.
 A new maritime *Polygonum* from Nova Scotia. *Rhodora* 16: 187-189.
 A northern variety of *Aster linariifolius*. *Rhodora* 16: 192-194.
 Two Newfoundland *Antennarias*. *Rhodora* 16: 196, 197.

- The Cambridge British Flora [C. E. Moss]. (Review) *Rhodora* 16: 198-200.
 The western variety of *Maianthemum canadense*. *Rhodora* 16: 210, 211.
 (With J. F. Macbride) The North American varieties of *Arctostaphylos Uva-ursi*. *Rhodora* 16: 211-213.
Carex leptoneura a valid species. *Rhodora* 16: 213, 214.

1915

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 I. Some new or unrecorded Compositae chiefly of northeastern America. *Rhodora* 17: 1-20. II. (With H. St. John) Some anomalous species and varieties of *Bidens* in eastern North America. 20-25.
 The North American representatives of *Dryopteris spinulosa*, var. *dilatata*. *Rhodora* 17: 44-48.
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 Altitudinal limits in Connecticut, a correction. *Rhodora* 17: 88.
 Two variations of *Silene antirrhina*. *Rhodora* 17: 96, 97.
 A handy book on trees and shrubs. [F. S. Mathews. *Field Book of American Trees and Shrubs*.] (Review) *Rhodora* 17: 103, 104.
Michaux's Panicum muricatum. *Rhodora* 17: 105-107.
 The American variations of *Lycopodium annotinum*. *Rhodora* 17: 123-125.
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 An albino *Viola rostrata*. *Rhodora* 17: 180.
 (With K. M. Wiegand) The genus *Euphrasia* in North America. (Contributions from the Gray Herbarium of Harvard University N. S. 44.) *Rhodora* 17: 181-201.
 The natural history of ancient Vinland and its geographic significance. *Bull. Am. Geogr. Soc.* 47: 686, 687.
 The identity of *Circaea latifolia* and the Asiatic *C. quadrisulcata*. *Rhodora* 17: 222-224.
 The characters and range of *Carex laevivaginata*. *Rhodora* 17: 231, 232.
 (With H. St. John) The occurrence of *Botrychium virginianum*, var. *europaeum* in America. *Rhodora* 17: 233, 234.

1916

- (With C. A. Weatherby) The genus *Puccinellia* in eastern North America. (Contributions from the Gray Herbarium of Harvard University N. S. 46) *Rhodora* 18: 1-23.

- A pubescent form of *Salix Uva ursi*. *Rhodora* 18: 52.
Chelone glabra L., forma *rosea*, n. f. *Rhodora* 18: 72.
 The occurrence of *Polygonum acadiense* in Denmark. *Bot. Tidsk.* 34: 253-255.
 A calciphile variety of *Andromeda glaucophylla*. *Rhodora* 18: 100-102.
Prunus virginiana the correct name of the choke cherry. *Rhodora* 18: 140, 141.
 The genus *Sabatia* in New England. *Rhodora* 18: 145-152.
 Some notes on *Spartina*. *Rhodora* 18: 177-180.
 The representatives of *Trisetum spicatum* in eastern America. *Rhodora* 18: 195-198.
 Some allies of *Antennaria alpina* from Newfoundland and the Labrador Peninsula. *Rhodora* 18: 236-238.
 The natural history of ancient Wineland and its geographical significance. [Preliminary outline of lecture.] *Bull. Bklyn. Inst.* 16: 266, 267.

1917

- The genus *Elatine* in eastern North America. *Rhodora* 19: 10-15.
 A new *Juncus* from Cape Cod. *Rhodora* 19: 17-20.
 The genus *Erechtites* in temperate North America. *Rhodora* 19: 24-27.
 A new *Luzula* from eastern Canada. *Rhodora* 19: 38, 39.
 The specific characters of *Hepatica americana*. *Rhodora* 19: 45, 46.
Helianthemum dumosum on the mainland of New England. *Rhodora* 19: 58-60.
 The variations of *Polygonum pensylvanicum*. *Rhodora* 19: 70-73.
 Two new maritime plants of northeastern North America. *Rhodora* 19: 76.
 The identity of *Circaea canadensis* and *C. intermedia*. *Rhodora* 19: 85-88.
 A new *Cardamine* from southern Maine. *Rhodora* 19: 91, 92.
Carex gynocrates in Pennsylvania. *Rhodora* 19: 110.
 Merritt Lyndon Fernald. Harvard College, Class of 1897, Fifth Report 5: 92, 93.
 A diagnostic character of *Nuphar microphyllum*. *Rhodora* 19: 111.
Tiarella cordifolia L., forma *parviflora*, n. f. *Rhodora* 19: 132.
 Contributions from the Gray Herbarium of Harvard University N. S. 50.
 I. Some *Polygonums* new to North America. *Rhodora* 19: 133-135,
 II. New or critical species or varieties of *Ranunculus*. 135-139,
 III. Some color forms of American *Anemones*. 139-141, IV. New
 species, varieties and forms of *Saxifraga*. 141-144, V. A new *Vitis*
 from New England. 144-147, VI. *Gentiana clausa* a valid species.
 147, 148, VII. Some forms of American *Gentians*. 149-152, VIII.
 Some new or critical plants of eastern North America. 152-155.
 The tardy flowering of plants in eastern Massachusetts in the spring of 1917. *Rhodora* 19: 219, 220.
 A new Alpine willow from the White Mountains. *Rhodora* 19: 221-223.

The boreal and sub-alpine variety of *Spiraea latifolia*. *Rhodora* 19: 254, 255.

A remarkable colony of *Bidens* in Connecticut. *Rhodora* 19: 257-259.

1918

American variations of *Epilobium*, section *Chamaenerion*. *Rhodora* 20: 1-10.

The American range of *Botrychium lanceolatum*. *Rhodora* 20: 19, 20.

Some American *Epilobiums* of the section *Lysimachion*. *Rhodora* 20: 29-39.

The North American *Littorella*. *Rhodora* 20: 61, 62.

The validity of *Oxalis americana*. *Rhodora* 20: 76-78.

Rosa blanda and its allies of northern Maine and adjacent Canada. *Rhodora* 20: 90-96.

The geographic affinities of the vascular floras of New England, the Maritime Provinces and Newfoundland. *Am. Jour. Bot.* 5: 219-236.

The contrast in the floras of eastern and western Newfoundland. *Am. Jour. Bot.* 5: 237-247.

The diagnostic character of *Vallisneria americana*. *Rhodora* 20: 108-110. (With K. M. Wiegand) Some new species and varieties of *Poa* from eastern North America. *Rhodora* 20: 122-127.

The American representatives of *Equisetum sylvaticum*. *Rhodora* 20: 129-131.

Some allies of *Rhynchospora macrostachya*. *Rhodora* 20: 138-140.

The specific identity of *Bidens hyperborea* and *B. colpophila*. *Rhodora* 20: 146-150.

Carex paupercula Michx., var. *brevisquama*, n. var. *Rhodora* 20: 152.

The specific validity of *Limosella subulata*. *Rhodora* 20: 160-164.

Solidago racemosa Greene, forma *leucantha*, n. f. *Rhodora* 20: 172.

An intergeneric hybrid in the *Cyperaceae*. *Rhodora* 20: 189-191.

Some North American representatives of *Braya humilis*. *Rhodora* 20: 201-203.

1919

Contributions from the Gray Herbarium of Harvard University N. S. 57.

I. The unity of the genus *Arenaria*. *Rhodora* 21: 1-7, II. The type of the genus *Alsine*. 7-9, III. The earlier names for *Alsineopsis*. 9-12, IV. The American representatives of *Arenaria sajanensis*. 12-17, V. The specific identity of *Arenaria groenlandica* and *A. glabra*. 17-21, VI. The American variations of *Arenaria verna*. 21, 22.

Helianthemum Bicknellii and *B. propinquum*. *Rhodora* 21: 36, 37.

Carex flava, var. *gaspensis* in Vermont. *Rhodora* 21: 40.

Lithological factors limiting the ranges of *Pinus Banksiana* and *Thuja occidentalis*. (Contributions from the Gray Herbarium of Harvard University N. S. 58.) *Rhodora* 21: 41-67.

- (With R. C. Bean & C. H. Knowlton) Plans for the 1919 spring field trip of the New England Botanical Club. *Rhodora* 21: 86-88.
- Rubus idaeus* and some of its variations in North America. *Rhodora* 21: 89-98.
- Bidens connata* Muhl., var. *gracilipes*, n. var. *Rhodora* 21: 103, 104.
- Panicum* § *Capillaria* in New England. *Rhodora* 21: 110-114.
- Two new *Myriophyllums* and a species new to the United States. *Rhodora* 21: 120-124.
- A new *Polygonum* from southeastern Massachusetts. *Rhodora* 21: 140-142.
- (With R. C. Bean & C. H. Knowlton) Field trips of the New England Botanical Club, 1919. *Rhodora* 21: 143.
- The identity of *Angelica lucida*. *Rhodora* 21: 144-147.
- The white-flowered bird's-eye primrose. *Rhodora* 21: 148.
- The variations of *Ranunculus repens*. *Rhodora* 21: 169.
- Coreopsis rosea* Nutt., forma *leucantha*, n. f. *Rhodora* 21: 171.
- A flora of northeastern Pennsylvania. [A. Twining] (Review) *Rhodora* 21: 172.
- Nymphozanthus* the correct name for the cow lilies. *Rhodora* 21: 183-188.
- Lomatogonium* the correct name for *Pleurogyne*. *Rhodora* 21: 193-198.

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- Some variations of *Cardamine pratensis* in America. *Rhodora* 22: 11-14.
- The northern variety of *Ranunculus hispidus*. *Rhodora* 22: 30, 31.
- Polygala paucifolia* Willd., forma *vestita*, n. f. *Rhodora* 22: 32.
- The American varieties of *Pyrola chlorantha*. *Rhodora* 22: 49-52.
- Scirpus acutus* Muhl. *Rhodora* 22: 55, 56.
- The American *Ammophila*. *Rhodora* 22: 70, 71.
- Juncus Gerardi* Loisel., var. *pedicellatus*, n. var. *Rhodora* 22: 76.
- A flora of the Penobscot Bay Region. [A. F. Hill. The vascular flora of the eastern Penobscot Bay Region.] (Review) *Rhodora* 22: 91-96.
- A new *Digitaria* from New Hampshire. *Rhodora* 22: 101-104.
- (With W. Deane) A new albino raspberry. *Rhodora* 22: 112.
- Pyrola rotundifolia* and *P. americana*. *Rhodora* 22: 121-123.
- Oxalis Montana*. *Rhodora* 22: 143, 144.
- Gaultheria procumbens* L., forma *suborbiculata*, n. f. *Rhodora* 22: 155, 156.
- Lactuca hirsuta* Muhl., forma *calvifolia*, n. f. *Rhodora* 22: 156.
- Rubus recurvicaulis* Blanchard, var. *armatus*, n. var. *Rhodora* 22: 168.
- (With K. M. Wiegand) Studies of some boreal American *Cerastiums* of the section *Orthodon*. *Rhodora* 22: 169-179.
- Brainerd & Peitersen's Blackberries of New England. (Review) *Rhodora* 22: 185-191.
- Ropes Memorial Lectures: Eighth Course on Botany. Announcement. 3 pp.

1921

The North American representatives of *Scirpus cespitosus*. *Rhodora* 23: 22-25.

(With C. A. Weatherby) *Equisetum fluviatile* or *E. limosum*? *Rhodora* 23: 43-47.

Juniperus communis L. var. *megistocarpa* Fernald & St. John, n. var.; *Rubus arcuans* Fernald & St. John, n. sp.; *Lathyrus palustris* L. var. *retusus* Fernald & St. John, n. var.; *Bartonia iodandra* Robinson, var. *sabulonensis* Fernald, n. var.; *Lycopus uniflorus* Michx., var. *ovatus* Fernald & St. John, n. var. *In*: St. John, H. Sable Island with a catalogue of its vascular plants. *Proc. Boston Soc. Nat. Hist.* 36: 58, 78, 79, 81, 82, 89, 90, 92.

Scutellaria epilobiifolia. *Rhodora* 23: 85, 86.

The Gray Herbarium Expedition to Nova Scotia, 1920. (Contributions from the Gray Herbarium of Harvard University N. S. 63.) *Rhodora* 23: 89-111, 130-152, 153-171, 184-195, 223-245, 257-278, 284-300.

(With H. St. John) The American variations of *Silene acaulis*. *Rhodora* 23: 119, 120.

(With W. J. V. Osterhout & R. Thaxter) Lincoln Ware Riddle. *Science* N. S. 54: 9.

The geographic distribution of hybrids. *Science* N. S. 54: 73, 74.

The Vienna Code. *Jour. Bot.* 59: 233, 234.

1922

Some variations of *Cakile edentula*. *Rhodora* 24: 21-23.

Notes on *Sparganium*. *Rhodora* 24: 26-34.

Brassica arvensis (L.) Kuntze, var. *Schkuhriana* (Reichenb.) n. comb. *Rhodora* 24: 36.

(With C. A. Weatherby) Varieties of *Geum canadense*. *Rhodora* 24: 47-50.

The generic name *Phragmites*. *Rhodora* 24: 55, 56.

(With H. St. John) *Salix vestita* and its varieties. *In*: St. John. A botanical exploration of the north shore of the Gulf of St. Lawrence including an annotated list of the species of vascular plants. Canada Dept. Mines Victoria Mem. Mus. Mem. 128: 44, 45. *Antennaria glabrifolia*. 55, 56.

Earl J. Grimes [Appreciation of] *In*: Davis, D. W. Earl Jerome Grimes, p. 325. *William & Mary Lit. Mag.* 19: 314-326.

Lysimachia terrestris (L.) BSP., var. *ovata* (Rand & Redfield) n. comb. *Rhodora* 24: 76.

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- Polypodium virginianum* and *P. vulgare*. (Contributions from the Gray Herbarium of Harvard University N. S. 66) *Rhodora* 24: 125-142.
 Notes on the Flora of western Nova Scotia, 1921. (Contributions from the Gray Herbarium of Harvard University N. S. 67) *Rhodora* 24: 157-164, 165-180, 201-208.
 Hoffmann's Flora of Berkshire County, Massachusetts. (Review) *Rhodora* 24: 183-187.
 The American variations of *Linnaea borealis*. *Rhodora* 24: 210-212.
 The northern variety of *Asperella hystrix*. *Rhodora* 24: 229-231.

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- The southern variety of *Thelypteris fragrans*. *Rhodora* 25: 1-4.
 The native tansy of Newfoundland. *Rhodora* 25: 13-16.
Vaccinium uliginosum and its var. *alpinum*. *Rhodora* 25: 23-25.
 The estuarine *Bidens* of the Miramichi. *Rhodora* 25: 43, 44.
 Another orchid new to New England. *Rhodora* 25: 47, 48.
 Nomenclatorial transfers in *Mariscus*. *Rhodora* 25: 49-54.
 The identities of the Sand Cherries of eastern America. *Rhodora* 25: 69-74.
Empetrum nigrum L., forma *purpureum* (Raf.) n. comb. *Rhodora* 25: 83.
 The Gentian of the tidal shores of the Saint Lawrence. *Rhodora* 25: 85-89.
 The northern variety of *Geum virginianum*. *Rhodora* 25: 98, 99.
 Notes on the distribution of *Najas* in northeastern America. *Rhodora* 25: 105-109.
 Baffin Land plants collected by the MacMillan Expedition, 1922. *Rhodora* 25: 111-114.
Lycopodium sabinaefolium and *L. sitchense*. *Rhodora* 25: 166, 167.
 The American variety of *Scheuchzeria palustris*. *Rhodora* 25: 177-179.
 (With K. M. Wiegand) Notes on some plants of the Ontario and St. Lawrence Basins, New York. *Rhodora* 25: 205-214.

1924

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 Contributions from the Gray Herbarium of Harvard University N. S. 72.
 I. *Polystichum mohrioides* and some other subantarctic or Andean plants in the Northern Hemisphere. *Rhodora* 26: 89-95, II. The dwarf *Antennarias* of northeastern America. 95-102, III. The eastern American representatives of *Arnica alpina*. 103-107, IV. Some *Senecios* of eastern Quebec and Newfoundland. 113-122, V. New or recently restudied plants of eastern America. 122-127.

- Note on coastal plain distribution. *In*: D. W. Johnson & N. A. Stolfus. The submerged coastal plain and oldland of New England. *Science* N.S. 59: 291-298.
- A Flora of Springfield, Massachusetts. [L. Andrews. Catalogue of the Flowering Plants and Ferns of Springfield, Massachusetts.] (Review) *Rhodora* 26: 179, 180.
- Myriophyllum magdalenense*: a correction. *Rhodora* 26: 198.
- Juncus triglumis* and its American representative. *Rhodora* 26: 201, 202.
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- (With C. A. Weatherby) Comments on the proposals of the British Imperial Botanical Conference for modification of the International Rules of Nomenclature. Mimeographed. 6 pp.

1925

- (With J. F. Collins) The region of Mount Logan, Gaspé Peninsula. *Geogr. Rev.* 15: 84-91.
- The American representatives of *Lonicera caerulea*. *Rhodora* 27: 1-11.
- Two new *Epilobiums* of eastern America. *Rhodora* 27: 32-34.
- The validity of *Eleocharis quadrangulata*. *Rhodora* 27: 37-40.
- A White Mountain Flora. [A. S. Pease. Vascular Flora of Coos County, New Hampshire.] (Review) *Rhodora* 27: 52.
- Pontederia* versus *Unisema*. *Rhodora* 27: 76-81.
- Another *Arnica* from Newfoundland. *Rhodora* 27: 90-92.
- The Maritime Plantains of North America. *Rhodora* 27: 93-104.
- Botanical explorations in eastern Canada. *Harvard Alumni Bull.* 27: 1046-1051.
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- Erysimum Pallasii* (Pursh) n. comb. *Rhodora* 27: 171.
- The New England-Acadian shoreline. [D. Johnson] (Review) *Rhodora* 27: 187, 188.
- Resumé of lecture before Torrey Botanical Club. *Torreya* 25: 106, 107.
- Botanizing the unmapped Mountains of Gaspé and Newfoundland. [Preliminary summary of lecture.] *Bull. Harvard Club Boston.*
- Sparganium multipedunculatum* in eastern America. *Rhodora* 27: 190-193.
- The arctic variety of *Alopecurus aequalis*. *Rhodora* 27: 196-199.
- The identity of *Eriophorum callithrix*. *Rhodora* 27: 203-210.

1926

- Carex livida* and *C. Grayana*. *Rhodora* 28: 5-8.
- Bromus ciliatus* L., var. *denudatus* (Wiegand) n. comb. *Rhodora* 28: 20.
- The ragged Orchis of Newfoundland. *Rhodora* 28: 21, 22.
- Kate Furbish, Botanist. [L. H. Coburn] (Review) *Rhodora* 28: 36.

Two summers of botanizing in Newfoundland. (Contributions from the Gray Herbarium of Harvard University N. S. 76.) *Rhodora* 28: 49-63, 74-87, 89-111, 115-129, 145-155, 161-178, 181-204, 210-225, 234-241.

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1927

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Rehder's Manual of Cultivated Trees and Shrubs. (Review) *Rhodora* 29: 48-51.

Streptopus oreopolus in the White Mountains. *Rhodora* 29: 76.

Some varieties of *Artemisia borealis*. *Rhodora* 29: 93-95.

The romance of economic botany. [D. C. Peattie. *Cargoes and Harvests.*] (Review) *Rhodora* 29: 95, 96.

Arthur Stanley Pease, Botanist, Explorer and Mountaineer. *Amherst Grad. Quart.* 64: 467-470. *Amherst Alumni Council News* 1: 1-4.

Three new plants from the Lower St. Lawrence. *Rhodora* 29: 141-144.

Houstonia Faxonorum (Pease & Moore), n. comb. *In: L. Arsène. Contributions to the flora of St. Pierre et Miquelon.* *Rhodora* 29: 187, 188.

The American *Cardamine parviflora*. *Rhodora* 29, 191, 192.

The botanical evidence of marine conditions in Lake Melville, Labrador. *In: The Privy Council (British Empire). In the matter of the boundary between the Dominion of Canada and the Colony of Newfoundland in the Labrador Peninsula.* 8: 3936-3948.

Xyris montana in eastern Massachusetts. *Rhodora* 29: 222, 223.

Axyris amaranthoides in eastern America. *Rhodora* 29: 223, 224.

Leiophyllum versus *Dendrium*. *Rhodora* 29: 225-227.

(With C. A. Weatherby) Proposed additions to the list of "Nomina Conservanda". (Mimeographed) 1-10.

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The authors of *Sonchus arvensis*, var. *glabrescens*. *Rhodora* 30: 19.

Contributions from the Gray Herbarium of Harvard University N. S. 79.

I. *Geocaulon*, a new genus of the Santalaceae. *Rhodora* 30: 21-24,

II. The American and eastern Asiatic *Beckmannia*. 24-27, III. The eastern American variety of *Polystichum Braunii*. 28-30, IV. The

American representatives of *Asplenium Ruta-muraria*. 37-43,

V. The eastern American occurrence of *Athyrium alpestre*. 44-49,

VI. *Primula* § *Farinosae* in America. 59-77, 85-104.

Victorin's *Les Équisétinées du Québec*. (Review) *Rhodora* 30: 79, 80.

The varieties of *Galium boreale*. *Rhodora* 30: 106, 107.

- (With S. L. Kelsey) A new *Oxytropis* from the Gaspé Coast. *Rhodora* 30: 121-124.
 [Erigeron compositus, var. trifidis] *Rhodora* 30: 122, 123.
Roripa islandica and *R. hispida*. *Rhodora* 30: 131-133.
 Contributions from the Gray Herbarium of Harvard University N. S. 82.
 I. The genus *Oxytropis* in northeastern America. *Rhodora* 30: 137-155, II. The North American species of *Anemone* § *Anemonanthea*. 180-188.
Eragrostis peregrina versus *E. Damiensiana*. *Rhodora* 30: 155-157.
 Unverified geographic ranges. *Science* N. S. 68: 145-149.
Panicum longifolium in Massachusetts. *Rhodora* 30: 190, 191.
 An American representative of *Calamagrostis epigejos*. *Rhodora* 30: 202-205.
 Some eastern American forms of *Senecio*. *Rhodora* 30: 224-226.

1929

- (With J. F. Collins et al.) Editorial announcement. *Rhodora* 31: 1-6.
Roripa islandica an invalid name. *Rhodora* 31: 17, 18.
 Contributions from the Gray Herbarium of Harvard University N. S. 83.
 I. (With C. A. Weatherby) Schmidel's Publication of *Thelypteris*. *Rhodora* 31: 21-26, II. A study of *Thelypteris palustris*. 27-36, III. Four grasses of eastern America. 44-49, IV. (With A. E. Brackett) The representatives of *Eleocharis palustris* in North America. 57-77, V. A note of *Poa labradorica*. 78.
 A hybrid *Rynchospora*. *Rhodora* 31: 38.
 (With C. A. Weatherby) Proposed Amendments to the International Rules of Nomenclature. *Rhodora* 31: 91-96.
Polygonella articulata (L.) Meisn., forma *atrurubens*, n. f. *Rhodora* 31: 106.
Coptis trifolia and its eastern American representative. *Rhodora* 31: 136-142.
 The author of *Athyrium alpestre*. *Rhodora* 31: 165, 166.
 Die Subgenera, Sektionen und Subsektionen der Gattung *Lysimachia* L. In: H. Handel-Mazzetti. Die Pflanzenareale 2 Heft 5: Karte 44-49.
 Some relationships of the floras of the Northern Hemisphere. *Proc. Int. Congress Plant Sci.* 2: 1487-1507.
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Menyanthes trifoliata, var. *minor*. *Rhodora* 31: 195, 196.
Achillea sibirica in eastern America. *Rhodora* 31: 219, 220.

1930

- Contributions from the Gray Herbarium of Harvard University N. S. 87.
 I. *Ligusticum scoticum* of the North Atlantic and of the North Pacific. *Rhodora* 32: 7-9, II. *Carex marcocephala* and *C. antheri-*

coides. 9-11, IV. The complex *Bromus ciliatus*. 63-71, V. Some varieties of the amphigeon species of *Osmunda*. 71-76, VI. *Potamogeton alpinus* and *P. microstachys*. 76-83, VII. The identities of *Juncus canadensis* and of *J. brevicaudatus*. 83-88.

Unglaciated western Newfoundland. *Harvard Alumni Bull.* 32: 496-505.
Cornus L. Section *Arctocrania* Endl. *In: Regel, C. Die Pflanzenareale*
 2 Heft 7: Karte 69.

Willdenow's type of *Scirpus glaucescens*. *Rhodora* 21: 31, 32.

A new willow from the Côte Nord, Quebec. *Rhodora* 32: 112, 113.

The Cape Cod *Ceanothus*. *Rhodora* 32: 161, 162.

Gentiana procera Holm forma *laevicalyx*, n. f. *Rhodora* 32: 221.

The identity of *Alopecurus aequalis*. *Rhodora* 32: 221, 222.

The British representatives of *Juncus tenuis*. *Jour. Bot.* 68: 364-367.

1931

Scirpus pumilus in the Rocky Mountains. *Rhodora* 33: 23, 24.

International Botanical Address Book. *Rhodora* 33: 24.

Some rare plants of Scotland. *Jour. Bot.* 69: 8-10.

Specific segregations and identities in some floras of eastern North America and the Old World. (Contributions from the Gray Herbarium of Harvard University N. S. 93). *Rhodora* 33: 25-63. (Abstract in Fifth Int. Bot. Congress, Report of Proc.: 100, 101.)

Editorial announcement. *Rhodora* 33: 65-68.

A new blackberry from New Hampshire. *Rhodora* 33: 102-104.

Potentilla canadensis and *P. simplex*. *Rhodora* 33: 180-191.

Pedicularis labradorica. *Rhodora* 33: 193.

The home of *Kerria japonica*. *Rhodora* 33: 199, 200.

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Rubus Kennedyanus and *R. pergratus*, var. *terraenovae*. *In: R. B. Kennedy*. Further notes from southwestern Newfoundland. *Rhodora* 33: 208, 209.

Potamogeton tenuifolius Raf. *Rhodora* 33: 209-211.

Wild flowers of Kashmir. [B. O. Coventry.] (Review) *Rhodora* 33: 212.

A condensation of Gerarde's Herball. [Leaves from Gerard's Herball, M. Woodward.] (Review) *Rhodora* 33: 212.

Three *Antennarias* from Greenland. *Rhodora* 33: 222-224.

(With C. A. Weatherby) Some new plants from the Gaspé Peninsula.
Rhodora 33: 231-240.

1932

An Illustrated Flora of Quebec. [Flore Manuel de la Province de
 Québec, L. Marie.] (Review) *Rhodora* 34: 19, 20.

Botanizing on the Gaspé sea-cliffs. *Harvard Alumni Bull.* 36: 1-7.

Some genera and species of Rafinesque. *Rhodora* 34: 21-28.

Callitriche stagnalis on the lower St. Lawrence. *Rhodora* 34: 39, 40.

Two contemporary evaluations of the colonization by Sir Walter Raleigh.
Rhodora 34: 65, 66.

International Address Book of Botanists. (Review) *Rhodora* 34: 68.

Corylus americana, forma missouriensis. *Rhodora* 34: 96.

The New Hampshire record for *Rhynchospora Torreyana*. *Rhodora* 34:
 112, 113.

British Seaweeds. [A Handbook of British Seaweeds. L. Newton]
 (Review) *Rhodora* 34: 113, 114.

Another localized variety of *Bidens heterodoxa*. *Rhodora* 34: 116, 117.

Does *Juncus bulbosus* occur in Massachusetts? *Rhodora* 34: 117, 118.

An estuarine variety of *Mimulus ringens*. *Rhodora* 34: 118, 119.

Flora of the North Shore of the Gulf of St. Lawrence. [An Annotated
 List of Vascular Plants collected on the North Shore of the Gulf of
 St. Lawrence. H. F. Lewis.] (Review) *Rhodora* 34: 120.

An estuarine variety of *Gratiola lutea*. *Rhodora* 34: 147-149.

The linear-leaved North American species of *Potamogeton*, section *Axillares*. (Memoirs Gray Herbarium 3.) *Mem. Am. Acad.* 17: 1-183.

(With C. A. Weatherby) *Bartonia*: a comedy of errors. *Rhodora* 34:
 164-167.

(With C. A. Weatherby) *Pinus strobus* L., forma *prostrata*. *Rhodora*
 34: 168.

Lathyrus japonicus versus *L. maritimus*. *Rhodora* 34: 177-187.

(With C. A. Weatherby) *Picea glauca*, forma *parva*. *Rhodora* 34: 187-
 189.

(With C. A. Weatherby) *Abies balsamea* (L.) Mill., forma *hudsonia*.
Rhodora 34: 190, 191.

Druce's Comital Flora [The Comital Flora of the British Isles. G. C.
 Druce.] (Review) *Rhodora* 34: 191, 192.

Diarrhena festucoides. *Rhodora* 34: 204-206.

Notes on *Festuca octoflora*. *Rhodora* 34: 209-211.

(With C. A. Weatherby) *Picea rubens* Sarg., forma *virgata*. *Rhodora*
 34: 211.

Phragmites communis Trin., var. *Berlandieri*. *Rhodora* 34: 211, 212.

Carex Richardsonii in New England. *Rhodora* 34: 229-232.

Rydberg's Flora of the Prairies and Plains. (Review) *Rhodora* 34:
 243-247.

1933

- Recent discoveries in the Newfoundland flora. (Contributions from the Gray Herbarium of Harvard University N. S. 101.) *Rhodora* 35: 1-16, 47-63, 80-107, 120-140, 161-185, 203-223, 230-247, 265-283, 298-315, 327-346, 364-386, 395-403.
- (With B. L. Robinson & W. H. Weston, Jr.) Minute in the life and services of Professor Roland Thaxter. *Harvard Alumni Gaz.* 28: 73, 74.
- Diarrhena festucoides* again. *Rhodora* 35: 39, 40.
- Calamagrostis epigejos*, var. *georgica* in America. *Rhodora* 35: 64, 65.
- Two segregates in *Sporobolus*. *Rhodora* 35: 108-110.
- Hawaiian weeds. [Weeds of the Pineapple Fields of the Hawaiian Islands. H. St. John] (Review) *Rhodora* 35: 146.
- Callitriche anceps* in New England. *Rhodora* 35: 185, 186.
- Types of some American species of *Elymus*. *Rhodora* 35: 187-198.
- The slender-spiked *Spartina pectinata*. *Rhodora* 35: 258-260.
- The New York record of *Fraxinus profunda*. *Rhodora* 35: 293.
- Glyceria arkansana* in western New York. *Rhodora* 35: 294.
- Some forms of grasses. *Rhodora* 35: 316-319.
- Heterochromism in *Arctostaphylos Uva-ursi*, var. *coactilis*. *Rhodora* 35: 348-350.
- The type of *Teucrium canadense*. *Rhodora* 35: 392-395.
- (With S. K. Harris) Branching *Polygonatum pubescens*. *Rhodora* 35: 403-406.

1934

- Some transfers in *Digitaria* and *Paspalum*. *Rhodora* 36: 19-22.
- The name of the American Lotus. *Rhodora* 36: 23, 24.
- (With S. K. Harris) An additional note on the branching tendency in *Polygonatum*. *Rhodora* 36: 59, 60.
- Realignments in the genus *Panicum*. (Contributions from the Gray Herbarium of Harvard University N. S. 103.) *Rhodora* 36: 61-87.
- Some critical plants of Greenland. *Rhodora* 36: 89-97.
- A new *Primula* from the Grand Canyon of the Colorado. *Rhodora* 36: 117-119.
- (With A. R. Hodgdon) *Gaultheria procumbens* L., forma *accrescens* f. nov. *Rhodora* 36: 129.
- Four forms of Massachusetts plants. *Rhodora* 36: 194, 195.
- A conical sugar maple. *Rhodora* 36: 238, 239.
- Some beginnings of specific differentiation in plants. *Science* N. S. 79: 573-578.
- Draba* in temperate northeastern America. (Contributions from the Gray Herbarium of Harvard University N. S. 105.) *Rhodora* 36: 241-261, 285-305, 314-344, 353-371, 392-404.
- M. O. Malte as a systematic botanist. *Canada. Field-Nat.* 48: 91-93.

- (With C. A. Weatherby) Some inadequately characterized species of George Vasey. *Rhodora* 36: 346-348.
Agropyron trachycaulum versus *A. pauciflorum*. *Rhodora* 36: 417-420.
 Flora of Iceland and the Faeroes [C. H. Ostenfeld & J. Grøntved] (Review) *Rhodora* 36: 421, 422.

1935

- Economic plants [E. E. Stanford.] (Review) *Rhodora* 37: 31, 32.
Lemna cyclostasa an invalid name. *Rhodora* 37: 75, 76.
 (With L. Griscom) Three days of botanizing in southeastern Virginia. (Contributions from the Gray Herbarium of Harvard University N. S. 107.) *Rhodora* 37: 129-157, 167-189.
 Two new botanical journals [Phytologia and Claytonia] *Rhodora* 37: 162, 163.
Galium Brandegei. Leaf. West. Bot. 1: 184.
 Critical plants of the upper Great Lakes region of Ontario and Michigan. (Contributions from the Gray Herbarium of Harvard University N. S. 108.) *Rhodora* 37: 197-222, 238-262, 272-301, 324-341.
 Victorin's *Flore Laurentienne*. (Review) *Rhodora* 37: 305-307.
 Praeger's *Botanist in Ireland*. (Review) *Rhodora* 37: 308.
 Hitchcock's *Manual of the Grasses*. (Review) *Rhodora* 37: 369-372.
 Midsummer vascular plants of southeastern Virginia. (Contributions from the Gray Herbarium of Harvard University N. S. 109.) *Rhodora* 37: 378-413, 423-454.

1936

- Albino *Iris versicolor*. *Rhodora* 38: 52.
Gnaphalium calviceps, a correction. *Rhodora* 58: 52.
 Virginia records needing verification. *Claytonia* 2: 36, 37.
 Gray Herbarium. In: Report of the President of Harvard College . . . 1934-35. Off. Reg. Harvard Univ. 33 (no. 4): 297-302.
 Some forms in the Alismaceae. *Rhodora* 34: 73, 74.
 (With C. A. Weatherby and I. M. Johnston) Benjamin Lincoln Robinson. Harv. Univ. Gaz. 31: 107, 108.
 Nathaniel Lord Britton, 1859-1934. *Proc. Am. Acad.* 70: 505, 506.
 A smooth-husked hazel. *Rhodora* 38: 76.
 The resignation of James Franklin Collins. *Rhodora* 38: 101.
 Contributions from the Gray Herbarium of Harvard University N. S. 113.
 I. A new pondweed from Tennessee. *Rhodora* 38: 165-169, II. *Pilea* in eastern North America. 169, 170, III. Memoranda on *Ranunculus*. 171-178, IV. The nomenclature of *Sassafras*. 178, 179, V. Memoranda on *Aruncus*. 179-182, VI. Studies in *Solidago*. 201-229, VII. Memoranda on *Antennaria*. 229-231, VIII. Varieties of *Gnaphalium obtusifolium*. 231-233, IX. Minor forms and transfers. 233-239.
Prenanthes crepidinea in western New York. *Rhodora* 38: 300.

- Asplenium platyneuron* (L.) Oakes, var. *bacculum-rubrum*. *Rhodora* 38: 304.
 Dates of publication of Rydberg's *Flora of the Rocky Mountains and Adjacent Plains*. *Rhodora* 38: 329-331.
Hypericum mutilum L., var. *latisepalum*. *Rhodora* 38: 372.
 Plants from the outer coastal plain of Virginia. (Contributions from the Gray Herbarium of Harvard University N. S. 115.) *Rhodora* 38: 376-404, 414-452.

1937

- Petalostemon occidentale* (Gray) comb. nov. *Rhodora* 39: 28.
 Gray Herbarium. *In*: Report of the President of Harvard College . . . 1935-36. Off. Reg. Harvard Univ. 34 (no. 11): 298-302.
 Merritt Lyndon Fernald. Harvard College Class of 1897. Fortieth Anniversary Report 8: 42.
Braya humilis, var. *leiocarpa*. *Rhodora* 39: 276.
 (With L. Griscom) Notes on *Diodia*. (Contributions from the Gray Herbarium of Harvard University N. S. 118, no. 3.) *Rhodora* 39: 306-308.
 Nomenclatural transfers and new varieties and forms. (Contributions from the Gray Herbarium of Harvard University N. S. 118, no. 4.) *Rhodora* 39: 309-320.
 Local plants of the Inner Coastal plain of southeastern Virginia. (Contributions from the Gray Herbarium of Harvard University N. S. 120.) I. Account of a summer's collecting. *Rhodora* 39: 321-366, II. Enumeration and discussion of noteworthy species collected. 379-415, 433-459, III. Phytogeographic consideration. 465-491.
 Benjamin Lincoln Robinson (1864-1935). *Proc. Am. Acad.* 71: 539-542.
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 Biographical memoir of Benjamin Lincoln Robinson, 1864-1935. *Nat. Acad. Sci. Biog. Mem.* 17: 305-330.
 (With L. Griscom) Identity of *Lobelia glandulosa* Walt. *Rhodora* 39: 497.

1938

- Gray Herbarium. *In*: Report of the President of Harvard College . . . 1936-37. Off. Reg. Harvard Univ. 35 (no. 4): 309-314.
 A flora of Oklahoma [Oklahoma Flora. T. R. Stemen & W. S. Myers] (Review) *Rhodora* 40: 179-183.
Datura stramonium L. var. *inermis* (Juss.) comb. nov. *Rhodora* 40: 184.
Anaphalis margaritacea again. *Rhodora* 40: 218, 219.
 Dormancy of seeds. [The Vegetation of Cranbrook Lake bottom. C. Billington] (Review) *Rhodora* 40: 324.
 New species, varieties and transfers. (Contributions from the Gray Herbarium of Harvard University N. S. 122.) *Rhodora* 40: 331-358.

Noteworthy plants of southeastern Virginia. (Contributions from the Gray Herbarium of Harvard University N. S. 123.) *Rhodora* 40: 364-424, 434-459, 467-485.

Must all rare plants suffer the fate of *Franklinia*? *Jour. Franklin Inst.* 226: 383-397.

1939

Gray Herbarium. *In*: Report of the President of Harvard College . . . 1937-38. *Off. Reg. Harvard Univ.* 36 (no. 4): 350-361.

Hibiscus palustris L., forma *oculiroseus* (Britton), comb. nov. *Rhodora* 41: 112.

Oxypolis Canbyi (Coul. & Rose), comb. nov. *Rhodora* 41: 139.

How soon will the Manual be done? A plea for some undisturbed moments. *Science* N. S. 89: 329-332.

New species, varieties and transfers. (Contributions from the Gray Herbarium of Harvard University N. S. 126.) *Rhodora* 41: 423-461.

Last survivors in the flora of Tidewater Virginia. (Contributions from the Gray Herbarium of Harvard University N. S. 128.) *Rhodora* 41: 465-504, 529-599, 564-574.

1940

A new southern *Kalmia*. *Rhodora* 42: 53, 54.

Pennsylvanicus or *pennsylvanicus*? *Rhodora* 42: 94, 95.

Gray Herbarium. *In*: Report of the President of Harvard College . . . 1938-39. *Off. Reg. Harvard Univ.* 37 (no. 12): 390-397.

A pilose variety of *Diervilla lonicera*. *Rhodora* 42: 144.

Collection of plants in eastern Virginia and the Carolinas. *Yrbk. Am. Philos. Soc.* 1939: 207-209.

Albino forms of the beach pea. *Rhodora* 42: 157.

Gentiana Pennelliana, nom. nov. *Rhodora* 42: 198.

Potentilla gracilis Dougl., var. *pulcherrima* (Lehm.) comb. nov. *Rhodora* 42: 213.

Some spermatophytes of eastern North America. (Contributions from the Gray Herbarium of Harvard University N. S. 131.) *Rhodora* 42: 239-276, 281-302.

A century of additions to the flora of Virginia. (Contributions from the Gray Herbarium of Harvard University N. S. 133.) *Rhodora* 42: 355-416, 419-498, 503-521.

The "Flora Virginica" of Gronovius. *Chron. Bot.* 6: 27, 28.

Rehder's Manual [Manual of Cultivated Trees and Shrubs Hardy in North America. A. Rehder.] (Review) *Rhodora* 42: 502.

The problem of conserving rare native plants. *Smithsonian Report* 1939: 375-391. (Reprinted *Real Gardening* 3: No. 11, 66-76; No. 12, 33-43.)

1941

Geranium nemorale, Sukds., var. *Bicknellii* (Britton) comb. nov. *Rhodora* 43: 35, 36.

- Cornus canadensis* L., forma rosea, f. nov. Rhodora 43: 156.
 Gray Herbarium. In: Report of the President of Harvard College . . .
 1939-40. Off. Reg. Harvard Univ. 38 (no. 20): 371-379.
 Transfers in *Pyrola*. Rhodora 43: 167.
Elatine americana and *E. triandra*. Rhodora 43: 208-211.
 Two varieties of *Dicliptera brachiata*. Rhodora 43: 287.
 Varieties of *Acnidia altissima*. Rhodora 43: 288.
 The campestrine variety of *Froelichia floridana*. Rhodora 43: 336.
 Studies of estuarine, marsh and sand-flora of eastern Virginia and North
 Carolina. Yrbk. Am. Philos. Soc. 1940: 168, 169.
Phragmites communis versus *P. maximus*. Rhodora 43: 286, 287.
 Two forms of *Rhododendron maximum*. Rhodora 43: 336.
 A hybrid *Cornus* from Cape Breton. Rhodora 43: 411, 412.
Viburnum edule and its nomenclature. Rhodora 43: 481-483.
 Another century of additions to the flora of Virginia. (Contributions
 from the Gray Herbarium of Harvard University N. S. 139.) Rho-
 dora 43: 485-553, 559-630, 635-657.
 (As editor) The spelling of "*pensylvanica*" again. Rhodora 43: 556.

1942

- Gray Herbarium. In: Report of the President of Harvard College . . .
 1940-41. Off. Reg. Harvard Univ. 39 (no. 5): 367-375.
 Some historical aspects of plant taxonomy. Rhodora 44: 21-43.
Carex Bayardi, nom. nov. Rhodora 44: 71.
Macloviana as a specific name. Rhodora 44: 71, 72.
Carex corrugata from Alabama. Rhodora 44: 76.
Justicia mortuifluminis, nom. var. Rhodora 44: 92.
 Incidents of field-work with J. Franklin Collins. (Contributions from
 the Gray Herbarium of Harvard University N. S. 140.) Rhodora
 44: 98-147.
 Formal transfers in *Cyperus*. Rhodora 44: 151.
 Some color forms of *Gentiana Porphyrio*. Rhodora 44: 151, 152.
Betula pusilla (Nutt.) comb. nov. Rhodora 44: 189-191.
Pluchea purpurascens (Sw.) DC., var. *succulenta*, var. nov. Rhodora
 44: 227, 228.
 The scarcity of pink-flowered *Gentiana Poryphyrio*. Rhodora 44: 237,
 238.
 Misinterpretation of Atlantic Coastal Plain species. Rhodora 44: 238-246.
Hibiscus Moscheutos and *H. palustris*. Rhodora 44: 266-278.
Digitalis purpurea naturalized in Newfoundland. Jour. Am. Pharm.
 Assoc. Scientific Ed. 31: 248.
 Critical notes on *Carex*. (Contributions from the Gray Herbarium of
 Harvard University N. S. 144.) Rhodora 44: 281-331.
 Three transfers in the *Compositae*. Rhodora 44: 340.

Some early botanists of the American Philosophical Society. Proc. Am. Philos. Soc. 86: 63-71.

Ranunculus abortivus L., forma *coptidifolius*, forma nova. *Rhodora* 44: 408.

The seventh century of additions to the flora of Virginia. (Contributions from the Gray Herbarium of Harvard University N. S. 145.) *Rhodora* 44: 341-405, 416-452, 457-479.

Transfers in *Scirpus* § *Actaeogeton*. *Rhodora* 44: 479-484.

1943

An important bibliography. [John Torrey, A. D. Rodgers, III.] (Review) *Rhodora* 45: 28.

(With A. C. Kinsey) The edible wild plants of eastern North America. Cornwall-on-Hudson. xiv, 452 pp.

Scirpus Longii in North Carolina. *Rhodora* 45: 55, 56.

An invaluable reference work. [Geographical guide to the floras of the World, S. F. Blake & A. C. Atwood.] (Review) *Rhodora* 45: 56.

Two later homonyms. *Rhodora* 45: 111, 112.

The fruit of *Dirca palustris*. *Rhodora* 45: 117-119.

Scirpus Peckii in Canada. *Rhodora* 45: 168.

Contributions from the Gray Herbarium of Harvard University N. S. 148.

I. Five common rhizomatous species of *Muhlenbergia*. *Rhodora* 45: 221-239, II. Notes on *Danthonia*. 239-246, III. *Erianthus brevibarbis* and other species. 246-255, IV. Why not *Andropogon Gerardi*? 255-258, V. Studies in North American species of *Scirpus*. 279-296, VI. The identity of *Scleria setacea* of Poiret. 296, 297, VII. What is *Angelica triquinata*? 298-303, VIII. Notes on *Hieracium*. 317-325.

Types of Argentinian plants of Spegazzini. *Science* N. S. 97: 423.

A Flora of Kentucky. [An Annotated Catalog of Spermatophytes of Kentucky. E. L. Braun.] (Review) *Rhodora* 45: 277, 278.

Our varieties of *Barbarea vulgaris*. *Rhodora* 45: 304.

Our varieties of *Trifolium pratense*. *Rhodora* 45: 331.

Trifolium hybridum and its var. *elegans*. *Rhodora* 45: 331.

Centaurea nervosa in America. *Rhodora* 45: 331, 332.

Minor transfers and forms in *Cirsium*. *Rhodora* 45: 353, 354.

Our albino lupine. *Rhodora* 45: 356.

Eastern extension of *Cirsium Flodmani*. *Rhodora* 45: 356.

Virginian botanizing under restrictions. (Contributions from the Gray Herbarium of Harvard University N. S. 149.) *Rhodora* 45: 357-413, 445-480, 485-510.

Vicia tetrasperma, var. *tenuissima* in America. *Rhodora* 45: 480.

Trillium undulatum Willd. forma *Cleavelandicum* (Wood) comb. nov. *Rhodora* 45: 517, 518.

The Quebec stations for *Scirpus Peckii*. *Rhodora* 45: 518.

1944

- Overlooked species, transfers and novelties in the flora of eastern North America. (Contributions from the Gray Herbarium of Harvard University N. S. 150.) *Rhodora* 46: 1-21, 32-57.
- Setaria Faberii* in eastern America. *Rhodora* 46: 57, 58.
- The so-called keeled garlic of eastern Pennsylvania. *Rhodora* 46: 59, 60.
- A further item of *Lilium michiganense*. *Rhodora* 46: 86, 87.
- Spergula pentandra* in America. *Rhodora* 46: 88.
- Fimbristylis Baldwiniana* not the same as *F. annua*. *Rhodora* 46: 144, 145.
- Does *Trilisa* occur in Virginia? *Rhodora* 46: 148.
- Does *Cnicus benedictus* persist in our flora? *Rhodora* 45: 158.
- Jussiaea Michauxiana* nom. nov. *Rhodora* 46: 197, 198.
- An indispensable index to *Rhodora*. *Rhodora* 46: 200.
- Is *Hypochaeris glabra* established in our flora? *Rhodora* 46: 206.
- Continental Drift and Plant Distribution [D. H. Campbell] (Review) *Rhodora* 46: 249-251.
- The albino of *Epilobium latifolium*. *Rhodora* 46: 251, 252.
- Shrubs of Michigan [C. Billington] (Review) *Rhodora* 46: 254.
- Abram's Illustrated Flora of the Pacific States. (Review) *Rhodora* 46: 282-284.
- Two of Rafinesque's species of *Tradescantia*. *Rhodora* 46: 310, 311.
- Imagined wisdom without understanding. [A dictionary of American English on historical principles. W. A. Craigie & J. R. Hulbert.] (Review) *Rhodora* 46: 312-315.
- Is there any evidence of *Seriocarpus bifolius* in the Manual Range? *Rhodora* 46: 316.
- Gray Herbarium. In: Report of the President of Harvard College . . . 1941-42. Off. Reg. Harvard Univ. 41 (no. 23): 392-399; 1942-43. 41 (no. 25) 276-282.
- Is *Erigeron carolinianus* a valid American species? *Rhodora* 46: 323-330.
- The identities of *Epilobium lineare*, *E. densum* and *E. ciliatum*. *Rhodora* 46: 377-386.
- Satureja vulgaris* (L.) Fritsch, var. *neogaea*, var. nov. *Rhodora* 46: 388.
- Lycopus amplexans*, var. *pubens* in New England. *Rhodora* 46: 451, 452.
- Why *Acerates floridana*? *Rhodora* 46: 488, 489.
- The confused publication of *Monarda Russeliana*. *Rhodora* 46: 491-493.
- The geographic segregation of *Monarda fistulosa* and its var. *mollis*. *Rhodora* 46: 494-496.
- The validity of *Lithospermum latifolium*. *Rhodora* 46: 496, 497.

1945

- Ruellia* in the eastern United States. (Contributions from the Gray Herbarium of Harvard University N. S. 153.) *Rhodora* 47: 1-38, 47-63, 69-90.

- Perezia aletes* an Argentinian species. *Rhodora* 47: 47.
- Woody plants of Maine. [F. Hyland & F. H. Steinmetz] (Review) *Rhodora* 47: 143, 144.
- Minor forms and transfers. *Rhodora* 47: 144.
- Botanical specialties of the Seward Forest and adjacent areas of south-eastern Virginia. (Contributions from the Gray Herbarium of Harvard University N. S. 156.) *Rhodora* 47: 93-142, 149-182, 191-204.
- An incomplete flora of Illinois. [Flora of Illinois. G. N. Jones] (Review) *Rhodora* 47: 204-219.
- Contributions from the Gray Herbarium of Harvard University N. S. 157. I. Key to Antennaria of the "Manual Range". *Rhodora* 47: 221-235, 239-247, II. Transfers in and animadversions on Artemisia. 247-256, III. Senecio congestus. 256, 257, IV. Notes on eastern American *Luzula*. 265-271.
- Injury to herbarium specimens by extreme heat. *Rhodora* 47: 258-260.
- Senecio Smallii* Britton, forma tristis f. nov. *Rhodora* 47: 302.
- Contributions from the Gray Herbarium of Harvard University N. S. 159. Some North American Corylacea (Betulaceae). I. Notes on *Betula* in eastern North America. *Rhodora* 47: 303-329, II. Eastern North American representatives of *Alnus incana*. 333-362.
- Chamaedaphne calyculata* (L.) Moench. var. *latifolia* (Ait.) comb. nov. *Rhodora* 47: 390, 391.
- Handy Guide to Aquatic and Marsh Vegetation. [J. B. Moyle & N. Hotchkiss.] (Review) *Rhodora* 47: 395.
- "Ia." sometimes stands for Indiana. *Rhodora* 47: 404, 405.

1946

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Fredrick P. Gay

FREDERICK PARKER GAY

1874-1939

BY A. R. DOCHEZ

For some men fortune is favorable in determining the time at which they are born. Perhaps not very frequently but occasionally the spirit and interests of their period are fortuitously adjusted to the future development of those qualities within themselves which later become manifest in their creative activities. Such a man was Frederick Parker Gay. In the broad sense he was a biologist and he contained within himself, and throughout his life cultivated assiduously, two important aspects of that science which are essential to the progressive enlargement of its point of view and to the understanding of the basic components which are essential to the development of its endless potentialities. Dr. Gay had that training in and appreciation of exact experimental procedures so necessary for the reliable determination of facts and their relatedness and the perceptive sensibility of the artist so important in discovering the pattern which is the hidden foundation upon which the facts are arranged. All too frequently to the ordinary mind this integrated arrangement seems to be somewhat chaotic in nature.

Frederick Parker Gay was born in Boston, Massachusetts, on July 22, 1874. His parents were George Frederick Gay and Louisa Maria Parker. On both sides his American ancestry went back to the early 1600s and contained representative names of New England, names with which much of the early distinction and achievement of this country is associated. Thus the stock from which he sprang was replete with integrity, energy, and consciousness of high purpose, characteristics which have fashioned the sound and well-articulated skeleton which gives structural stability to this country.

In his youth Dr. Gay's interests were many and various and he exhibited a certain orientation toward the adventurous. While at school his versatility was manifested by his interest in baseball, sailing, chess and music, an interest which later became an important preoccupation of his life. In the summer

of 1894 he went on an Arctic expedition conducted by Dr. Frederick Cook and on his return suffered shipwreck on the coast of Greenland. On his safe arrival home he wrote a description of his experiences for the Boston newspapers.

During his junior year at college, Dr. Gay's health broke down and he embarked on an instructive trip around the world, returning to graduate with his class at Harvard University in 1897. Whether a love of travel resulted from this experience or whether he was fulfilling an already existing impulse, at all events he indulged this taste frequently during his life. Shortly thereafter he again journeyed around the world in 1899, this time as an assistant with a Johns Hopkins University Medical School commission for the study of bubonic plague and certain other diseases in the Philippine Islands. About thirty years later he returned to the same islands to study leprosy as a member of the Leonard Wood Memorial Commission. On his first trip to the Philippines he went as a voluntary soldier with the American forces to fight against Aguinaldo and participated in the capture of Antipolo.

Dr. Gay graduated from the Johns Hopkins Medical School in 1901. Since at that time the science of bacteriology was an integral part of that branch of medicine concerned with morbid anatomy, his early instruction was obtained under the supervision and guidance of the pathologist. An award of the first fellowship of the Rockefeller Institute for Medical Research opened for him the position of assistant demonstrator in pathology at the University of Pennsylvania, a position which he occupied from 1901-1903.

Gay had been accustomed to spending his summer vacations in Europe and this, in conjunction with his growing interest in the fundamental problems of microbiology, influenced him to seek association with one of the great masters of the science of that day, Jules Bordet in Brussels. From this stimulating personality Gay received inspiration which was to affect his thinking and activities throughout the rest of his life. Under the influence of Bordet he turned from his more purely bacteriological studies of dysentery, arising out of his early experience in the Philippines, to the serological phenomena accompan-

ing immunity, a collateral branch of microbiology that at the time was in the first stages of its development. This division of microbiology was later to become of great importance and significance for the full understanding of the series of events that accompany the struggle between host and infecting microorganism and that determine to a large extent the favorable or unfavorable outcome of infectious disease. At first Gay's attention was devoted to a study of the alexin (complement) fixation reaction, a specific test for infection with a variety of microorganisms. This field of investigation was in its infancy at the time but later was to become an immunological reaction of great practical and theoretical importance. The interest aroused by this experience persisted throughout his life and represented the initiation of a long and versatile series of contributions to the science of immunology. His enthusiasm for the subject decided him to translate into English and to publish, in 1909, his first book: "Studies in Immunity," by Bordet and his collaborators.

On Gay's return to the United States he first served as bacteriologist to the Danvers Insane Hospital in Massachusetts, 1906-1907, and later as instructor in pathology, 1907-1909, at the Harvard Medical School. At this time he developed a life-long and fruitful friendship with Elmer Ernest Southard, the distinguished psychiatrist, a relationship for which he later expressed his deep appreciation by the preparation and publication, in 1937, of Southard's life and letters, under the title of "The Open Mind," a book whose excellence exhibits the breadth and variety of Gay's intellectual and humane interests. This friendship was productive also in the field of science, for with Southard as a collaborator he carried on a long and detailed study of anaphylaxis, a phenomenon which at the time was attracting widespread interest but of which the broad significance was only beginning to be indicated.

Up to this time, 1910, bacteriology had not yet achieved administrative and teaching independence as a scientific discipline in the medical schools of this country but was still under the direction and control of departments of pathology. Growth and expansion under these circumstances had, however, been

rapid and significant and many important contributions to the knowledge of disease had been made. In this connection, it is a matter of some interest that in 1910 Gay was appointed Professor of Pathology at the University of California, although his experience in pathology as such was somewhat limited and his principal interest and all his publications lay in the field of bacteriology and immunology. While at California and with a department of his own his broad interests were manifested by a rapid expansion of the field of his activities. Studies during this period were concerned with the nature of antibodies, the mechanism of their formation, and their practical application to the diagnostic problems of infectious disease. Parallel with these studies research on the effectiveness of variations of antigenic structure and of methods of application of antigens for the purpose of inducing antibody formation were actively carried on. A number of specific infectious diseases, such as poliomyelitis, pneumonia, meningitis, influenza, hemolytic streptococcus infection, and typhoid fever, were extensively investigated from the standpoint of bacteriology, immunology and etiological diagnosis. The study of typhoid fever particularly occupied his attention and resulted in a number of original contributions dealing with the carrier state in typhoid fever and its experimental production in rabbits, the usefulness of typhoid vaccine both for purposes of prophylactic immunization against the disease and as a method of shortening its course by intravenous injection during the acute phase of the fever itself. In an effort to devise a reaction of significance for the purpose of indicating resistance against typhoid fever, Gay and his co-workers were led to develop the typhoidin test, which consisted in the intracutaneous injection of products of the typhoid bacillus. A positive reaction indicated local hypersensitivity to the organism and when positive appeared to be correlated with immunity to the disease and when negative to lack of resistance to infection. The test was also used to measure the efficiency of prophylactic vaccination. The interest arising from these studies led, in 1918, to the publication of a book entitled "Typhoid Fever," an attempt at exposition of the total problem of the disease. Its aim was to treat historically the

development and present status of our knowledge concerning this important malady as viewed from the standpoint of its mechanisms. The range of subject matter was very comprehensive, extending from modes of infection in typhoid fever through all its multifarious aspects to the various methods thought to be possibly efficacious in its treatment.

Toward the end of Gay's stay in California he succeeded in developing at that University bacteriology and immunology as independent sciences separate from pathology, a separation which led to his appointment, in 1921, as Professor of Bacteriology and Director of the newly organized department. In 1923, Gay left the University of California and came to Columbia University as Professor and Executive Officer of the Department of Bacteriology, a department already distinguished both as to achievement and leadership and which had attained independence from pathology as early as 1909.

Gay at once took advantage of his new opportunities for the purpose of improving and expanding his teaching facilities, giving special attention to the development of graduate instruction leading to the degree of Doctor of Philosophy in Bacteriology awarded by the Faculty of Pure Science. The candidates for this degree were wisely limited in number in order to correspond with the demand for such graduates in the academic world.

Attracted by Gay's leadership the staff of the department grew rapidly in size and concurrently the investigative interests, by virtue of his broad experience, expanded to cover all the most important aspects of the fields of bacteriology and immunology. The breadth of these interests is well illustrated in the large monographic textbook, published in 1935, by Gay and his collaborators, entitled "Agents of Disease and Host Resistance." The two divisions of scientific thought which are implied in the title of this book, which recounts the interaction of disease causes and the defenses against them, are inextricably interwoven. Agents of disease are either inanimate, like poisons and the various forms of physical injury, or animate, consisting of very small microorganisms such as bacteria, fungi, protozoa, rickettsiae, and the filterable viruses. Gay directed his own at-

tention and that of his department to the study of these agents of disease and, at the same time, to the phenomena of resistance or immunity against infection with such organisms. Exploration roamed over a large portion of both of these extensive fields.

The great variety of subjects that were comprised in Gay's experience and knowledge are illustrated in the numerous publications from his department on the subject of the filterable viruses of poliomyelitis, encephalitis, cowpox, tobacco mosaic and bacteriophage, a type of virus that destroys bacterial cells by causing them to undergo solution. The general field of bacteriology was also extensively covered by studies of protozoa, spirochetes, rickettsiae, infections due to anaerobic bacteria and such oral diseases as dental caries and Vincent's angina. Investigation carried on also dealt with such general subjects as serological and cellular immunity, the relationship of hormones and vitamins to resistance to infection, bacterial mutation, the mode of action of bacterial toxins, anaphylaxis and other forms of protein and bacterial hypersensitivity, chemotherapy and certain non-specific agents such as lysozyme which also effect the destruction of bacteria. Gay himself was especially interested in both local and general immunity and the tissue mechanism in the body which results in antibody formation. The role of the white cells of the blood in resistance to infection had been clearly shown originally by Metchnikoff. The experiments of Gay and his collaborators showed clearly that although the circulating cells are important, they are not nearly so important with certain virulent bacteria, like the hemolytic streptococcus, as are the fixed and semi-motile mononuclear cells of what is called the reticulo-endothelial system. Years of study by him and his associates have brought into prominence those cells which not only are able to dispose of bacteria that resist the leucocytes but also would seem to have an important function in forming the antibodies of the blood serum. His concept was that a return to the consideration of the significance of these cells in acquired immunity, as well as in natural resistance, is of great importance.

Gay's conception of his own science, that of bacteriology, as exemplified in his life interests and work is best expressed in

his own words: "The science of today and of tomorrow is in its very nature incomplete and imperfect; it is only in retrospect that a science approaches orderliness and perfection. To most of us for most of our lives the fascination and hope of a science lie in its fragmentary present and future. The desire to supplement our incomplete knowledge of today is what drives us to hypothesis and continued experiment. Now and again one of our guesses will yield a fundamental truth to the edifice we are forever building. What then is the future of bacteriology? Does it lie in adapting blindly to our work the larger bodies of fact and method of what we call a more fundamental science like chemistry? I venture to think that the progress of each science lies in discovering new methods of its own as it always has. The modern study of viruses, although largely in the hands of bacteriologists, has developed new biological, chemical, and physical approaches and brought us closer to an enlarged, though by no means final, interpretation of life itself. In the study of the historical background of our science lies a check on over-emphasis on any one line of investigation, as well as a stimulus to renewed attack."

The variety and range of Gay's interests in medicine were the mirror of a sensitive mind that sought understanding of and expression in a number of fields of human experience unrelated to science. He early acquired a love of the classics, an influence that persisted throughout his life and that gave him a discriminating appreciation of words, their exact meaning and derivation. This attainment endowed his lectures with a quality of scholarly refinement and perfection of arrangement and expression that made a deep and lasting impression on young medical students. This artistic talent also found an outlet in his appreciation of literature and especially of poetry, the latter leading him once to pose the question whether one good sonnet might, perhaps, not be worth more than a sheaf of scientific papers. Belonging also to this side of his personality was his love of music and his deep satisfaction in the companionship of those of his friends who were distinguished musicians.

Gay's early experience in Arctic exploration initiated his impulse for adventure and travel which he later satisfied by

numerous trips to both near and distant parts of the earth. He was a charter member of the Explorers Club. He made three journeys around the world, the last of which began with a survey of leprosy for the Leonard Wood Memorial Commission for the Eradication of Leprosy for which he visited Honolulu and Japan and all the leprosaria in the Philippines, spending two months at Culion, the largest leper colony in the world. At this time he served as Chairman of the Advisory Committee on Research of the Leonard Wood Memorial. This spirit of adventure and interest in the unusual was reflected in the multiplicity of his approaches to the scientific problems of medicine.

Gay, by virtue of his distinguished position in research and medical education, shared generously in the honors and rewards that science bestows on its more outstanding devotees. Through his early affiliation with Bordet he was a member of the Société Belge de Biologie. He was also a Commander of the Order of the Crown of Belgium and served as exchange professor from Columbia University to the Belgian universities. He served as a Major in the Medical Corps of the United States Army in World War I and from 1917-1918 as a member of the Division of Medical Sciences of the National Research Council functioning as its Chairman and later as Chairman of its Medical Fellowship Board. In 1929 he served on the Board of Directors of the Columbia School of Tropical Medicine in Porto Rico, and in 1932 he received the degree of Doctor of Science from George Washington University. He was a member of many prominent scientific societies in America and frequently served as their president. Gay was elected a member of the National Academy of Sciences in 1939.

Gay had a natural love of the land, especially of his native soil of New England. This he satisfied by the devoted care of his farm at New Hartford, Connecticut, where he manifested an absorbing interest in everything that grew. He spent much time motoring through the countryside and getting a picture of his ancestral background; of pioneer migrations and the trades and skills that developed the Yankee character.

A man with such diversified gifts of mind and soul attracted a wide circle of devoted friends and associates. This affectionate regard, which all who knew him intimately learned to share, was sometimes difficult for others to understand whose association with him was only brief. Gay was somewhat retiring, and his nature had in it a certain shyness which did not permit an easy approach in establishing human relationship. Superficial impressions of this kind, however, do not do justice to a warmheartedness of character that was capable of forging such strong bonds of affection with those who were close to him.

Gay died on July 14, 1939, and in the words of a friend and associate, "His years of service were dedicated to the accomplishing of aids and benefits to mankind through patient and careful scientific research, and the full life of the man and the scholar is fittingly summed up by the brief inscription placed upon the simple granite monument over his ashes in the historic Town Hill Cemetery at New Hartford, Conn., banked by laurel and evergreens and overlooking the country hillsides:—

"To know, to search and to seek out wisdom'."

The assistance of Professor Claus W. Jungblut in the preparation of this memoir is gratefully acknowledged.

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

- Amer. Jour. Hyg.=American Journal of Hygiene
 Amer. Jour. Med. Sci.=American Journal of the Medical Sciences
 Ann. Inst. Past.=Annales de l'Institut Pasteur
 Arch. Int. Med.=Archives of Internal Medicine
 Arch. Path. Lab. Med.=Archives of Pathology and Laboratory Medicine
 Aust. Jour. Exp. Biol. Med. Sci.=Australian Journal of Experimental
 Biology and Medical Science
 Boston Med. Surg. Jour.=Boston Medical and Surgical Journal
 Bull. Hist. Med.=Bulletin of the History of Medicine
 Calif. State Jour. Med.=California State Journal of Medicine
 Centralbl. f. Bakt.=Zentralblatt für Bakteriologie
 Columbia Univ. Quart.=Columbia University Quarterly
 Ergebn. d. Immu.=Ergebnisse der Immunitätsforschung
 Internat. Clin.=International Clinics
 Johns Hopkins Hosp. Bull.=Johns Hopkins Hospital Bulletin
 Jour. Amer. Med. Assn.=Journal of the American Medical Association
 Jour. Bact.=Journal of Bacteriology
 Jour. Biol. Chem.=Journal of Biological Chemistry
 Jour. Exp. Med.=Journal of Experimental Medicine
 Jour. Immunol.=Journal of Immunology
 Jour. Infect. Dis.=Journal of Infectious Diseases
 Jour. Lab. Clin. Med.=Journal of Laboratory and Clinical Medicine
 Jour. Med. Res.=Journal of Medical Research
 Med. Commun.=Medical Communications
 Physiol. Rev.=Physiological Reviews
 Prac. Lib. Med. Surg.=Practitioners Library of Medicine and Surgery
 Proc. Assn. Res. Nerv. Mental Dis.=Proceedings of the Association for
 Research in Nervous and Mental Diseases
 Proc. Soc. Exp. Biol. Med.=Proceedings of the Society for Experimental
 Biology and Medicine
 Sat. Rev. Lit.=Saturday Review of Literature
 Trans. Assn. Amer. Phys.=Transactions of the Association of American
 Physicians
 Trans. Congr. Amer. Phys. Surg.=Transactions of the Congress of Ameri-
 can Physicians and Surgeons
 Trans. Fifteenth Internat. Congr. Hyg. Demog.=Transactions of the Fif-
 teenth International Congress of Hygiene and Demography
 Univ. Calif. Chron.=University of California Chronicle
 Univ. Calif. Publ. Pathol.=University of California Publications in
 Pathology
 Univ. Penna. Med. Bull.=University of Pennsylvania Medical Bulletin

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EB Hart

EDWIN BRET HART

1874-1953

BY CONRAD A. ELVEHJEM

In a short obituary of Dr. S. M. Babcock, Professor E. B. Hart started with these words, "To have enjoyed for a quarter of a century the intimate and steadfast friendship of a professional associate and a truly great man is, indeed, a rare privilege, and yet such has been my good fortune in my association with Stephen Moulton Babcock." Similarly, I have had the good fortune of knowing Professor Hart for a period of 32 years. I first met him as a student in an elementary course in agricultural chemistry in 1921. In my senior year he called me to his office and told me to take over teaching duties in the laboratory immediately since one of the assistants was leaving for a new position. Many of his teaching and research assistants were appointed under similar circumstances. This was the beginning of my close association and intimate friendship with this great teacher, research worker and advisor—an association which continued until the time of his death. During the past twenty-five years hardly a day passed that we did not meet for a conference or just a chat.

Edwin Bret Hart was born near Sandusky, Ohio, on December 25, 1874, the son of William and Mary Hess Hart, and the youngest of their family of 14. He was raised by his older brothers and sisters because his mother died in his infancy. As a student in Sandusky High School from which he graduated in 1892, he came in contact with Dr. E. L. Moseley, a teacher of physics and biology who first interested him in science. In the words of Professor Hart, "Professor Moseley not only interested us in science, but his fine character was a glorious example of decent manhood for young men. . .". After high school Hart proceeded to the University of Michigan where he studied chemistry and medicine.

While at Michigan he was an assistant to a distinguished professor of analytical chemistry, Dr. E. D. Campbell, who had lost his sight due to an explosion in the laboratory. His

association with Professor Campbell not only gave him early experience in teaching, but also placed him in close contact with an investigator who emphasized precision in experimental work. He often told of his relationship with Professor Campbell and frequently referred to the bicycle trips they took together. They used the then common tandem bicycle which required the same team work which they enjoyed in the laboratory. This ride was a daily occurrence and after a hard day in the laboratory Hart admitted that Campbell often supplied most of the power. His first scientific publication was with Professor Campbell entitled "On the Quantitative Determination of Hydrogen by Means of Palladous Chloride."

In 1897 he went to the New York State Experiment Station at Geneva, where he worked with Dr. W. H. Jordan. This gave him a new approach to experimental work. It was undoubtedly his experience at Geneva that encouraged him to go to Germany for advanced study in the field of chemistry and biochemistry. So—at the very beginning of the century he set out for Germany to study under the famous biochemist, Albrecht Kossel, who was then at Marburg. After a year Professor Kossel moved to Heidelberg and Hart accompanied him. Because of this transfer he was prevented from obtaining a higher degree. However, Professor Hart always felt that the right kind of training and experience were as valuable as degrees. He thoroughly enjoyed the student life in Heidelberg and often indulged in reminiscences of his experiences at that institution. He paid all his own expenses and purchased with his own money most of the supplies which he used in the laboratory. In later years when graduate students were dissatisfied with the small stipend which they received he would refer to his early experiences when he had to borrow money for advanced work. He published one paper as a result of his work in Kossel's laboratory but this experience introduced him to studies on proteins and all the intricacies of protein chemistry.

After two years in Germany, he returned to Geneva where he remained for a period of four years. In 1906 Dean W. A.

Henry of the College of Agriculture invited him to come to the University of Wisconsin as Head of the Department of Agricultural Chemistry and Chemist in the Experiment Station. Undoubtedly one important factor which attracted him to Wisconsin was that Dr. Stephen M. Babcock had been at the Geneva Experiment Station from 1882 to 1888 and Hart had become acquainted with his work. In his own words "I have profited enormously by going to Wisconsin and coming in contact with such men as Henry, Babcock, Russell, King, and Van Hise."

At the New York Experiment Station Hart became interested in two areas of research: the study of chemical changes in cheese during ripening and the importance of phosphorus compounds in plants and animals. With L. L. Van Slyke he published a number of papers dealing with enzymes in cheese, proteolytic compounds formed during the ripening of cheese and the relation of gases and salts to chemical changes taking place in the ripening process.

This early work brought him in contact with milk and dairy products and he continued his interest in this subject during his entire life. Shortly after coming to Wisconsin he published a simple method for the estimation of casein in cow's milk and studied the variations in the amount of casein in milks. His interest in this test was undoubtedly dependent on the fact that fifteen years earlier Dr. Babcock had developed a method for the estimation of fat in milk. In fact, the same centrifuge which Dr. Babcock had developed was used in the casein determination. Hart believed that the market price of milk should be based on the protein content as well as the percentage of fat. It is interesting to reflect that if as much attention had been given to the Hart casein test as was given to the Babcock fat test the dairy industry would today encounter less difficulty in coping with the surplus butterfat and the high price of butterfat as compared to the other constituents of the milk. In other words, in those early days greater emphasis might have been placed on the nutritional value of milk below the cream line.

With his interest in dairy products, Professor Hart de-

veloped a course in dairy chemistry which came to be recognized as a basic training for students in dairy and food technology. When Professor Hart retired no one in his department was capable of continuing this course but it was fortunate that one of his early students, Dr. Hugo H. Sommer, was on the staff of the Department of Dairy Industry and continued to give this course until his untimely death in 1953.

In 1903 Professor Hart published, with W. H. Andrews of the Geneva Experiment Station, a classical bulletin dealing with the status of phosphorus in food materials. This work clearly differentiated between the so-called bound or organic phosphorus and free or inorganic phosphorus. The following year Patten and Hart studied the principal phosphorus compounds in wheat bran and established the importance of what we know today as phytin. His interest in phosphorus continued after coming to Wisconsin and one of his first contributions from the Agricultural Chemistry Laboratory at Wisconsin was a paper by McCollum and Hart on "The Occurrence of a Phytin-Splitting Enzyme in Animal Tissues." In 1909 Hart and McCollum, in cooperation with Professor J. G. Fuller, established the role of inorganic phosphorus in the nutrition of animals. As a result of these studies McCollum concluded in 1910 that all of the phosphorus needed by an animal for skeleton, nuclein or phosphatide formation can be drawn from inorganic phosphate. This early work is especially significant in light of the tremendous developments that have taken place during the past forty years relating to phosphorylated organic compounds. In the summary of the Symposium on Phosphorus Metabolism held at Johns Hopkins University in 1951, the following statement was made: "Without question the exploration of the role of phosphorus in organisms has integrated and illuminated our understanding of the chemical nature of life processes beyond compare." Professor Hart pioneered in these early studies.

Since he had worked on proteins, especially casein, he was well aware that phosphorus was an important constituent of these molecules. He was also aware that proteins were rich in sulfur and that certain proteins contained as much as 2 per

cent on the dry weight basis. In 1909 Professor W. H. Peterson joined the department and Hart and Peterson published several papers on sulfur requirements of plants and animals. It is interesting to point out that in addition to McCollum and Peterson, Professor W. E. Totttingham had also become a member of the department and on the basis of these four men the department expanded into three areas—namely, the chemistry of animal metabolism, the chemistry of plant metabolism, and the chemistry of bacterial metabolism, with Professor Totttingham leading the work in plant chemistry and Professor Peterson developing the work in bacterial metabolism, or fermentation. A little later Dr. Steenbock joined the department and helped expand the work in the animal field.

Up until this time no specific emphasis had been placed on nutrition as such. Professor Hart had been interested in analytical chemistry, dairy chemistry, in proteins, enzymes and mineral elements, but he was now to pioneer in the new field of nutrition. A few years before Hart came to Wisconsin Dr. Babcock had initiated an experiment with growing heifers on restricted rations. The results of these experiments had not been conclusive and when Hart arrived in 1906 Dr. Babcock presented the results of his preliminary work and suggested to Dean Henry that a more comprehensive experimental plan should be inaugurated. The results of these studies with rations from single plant sources led to the publication of Research Bulletin No. 17 which has become a classical report since it laid the foundation for most of the modern research in nutrition.

It was about this time that limited federal funds were being made available for the support of research in Agricultural Experiment Stations. To be sure, the workers in those days were plagued with requests for reports of experimental results as are our modern workers. In order to be able to show progress in these reports Hart outlined two projects, namely, Adams No. 8, which dealt with mineral metabolism and mineral requirements of animals, and Adams No. 10, which dealt with vitamins and other organic nutrients in animal nutrition. This approach was typical of Hart's

philosophy—namely, to have a broad research program, one which was not confining but which allowed the investigator to modify his plan as new ideas became available. These two projects are still active in the Department of Biochemistry and modern investigators might well take cognizance of this type of philosophy. Practically all of Hart's work could be classified in these two categories.

No one individual has contributed more to research on minerals and vitamins in nutrition than Professor Hart. He was instrumental in the discovery that iodine is important in preventing goiter in animals and as a result of this discovery the livestock industry has been saved millions of dollars. He was an enthusiastic advocate of iodized salt for humans in order to prevent simple goiter in children, and served on committees which attempted to promote legislation which would make the iodization of salt compulsory. Later he and associates developed a method for the stabilization of iodine in salt which would insure the maintenance of a standard iodine content of salt.

In 1923 he initiated a comprehensive study on the relation of iron to nutrition and in cooperation with other members of the department clearly demonstrated, in 1928, that iron cannot be utilized for building hemoglobin unless it is accompanied by a small amount of copper. This discovery was presented by Professor Hart at the Federation Meetings in Ann Arbor, Michigan, in the spring of 1928. After his presentation he was given a standing ovation by the members. Such recognition has been given to only a few members of the American Society for Biological Chemists.

The demonstration that inorganic iron can be used for hemoglobin production only when it is accompanied by small amounts of copper was not only of importance in human nutrition but had real value in the prevention of anemia in farm animals, especially pigs. While Hart was pleased to see another discovery made in his laboratory put to immediate practical use, he was also interested in the basic aspects of this discovery and gave much attention to the mechanism by which copper functions in the living cell. Further studies on copper led

him into studies on other trace elements such as manganese, zinc, cobalt and boron. He and his coworkers demonstrated that both manganese and zinc have important functions in the animal body. Extensive attempts were made to demonstrate that boron was essential in animal nutrition, but it was impossible to produce a diet low enough in boron to produce any ill effect in the animal. It was recognized, of course, that boron is an important element in plant nutrition. He also studied the importance of cobalt in preventing anemia in cows and sheep before its relationship to vitamin B₁₂ was demonstrated.

He was one of the first workers to show the toxic effect of fluorine in farm animals and these early results impressed him with the deleterious effects of this element even when used in small amounts as a therapeutic agent. Extended investigations were undertaken under his direction in 1928 to study the physiological effects of fluorine at various levels upon farm and laboratory animals. This study was brought about because rock phosphate was being introduced as an economical source of calcium and phosphorus in practical animal feeding. This rock phosphate contained appreciable amounts of fluorine and, when fed at levels high enough to supply calcium and phosphorus, also supplied toxic levels of fluorine. It is interesting that these studies were made possible by a grant from the Ruhm Phosphate and Chemical Company of Mt. Pleasant, Tennessee, which was promoting the use of rock phosphate for animal feeding. These studies showed that rock phosphate was highly unsatisfactory as a mineral supplement because of the harmful effects of the fluorine present. As a result of these studies improvements were made in the production of rock phosphate so that a large portion of the fluorine was eliminated. Thus the original findings which appeared detrimental to the industry were used to develop procedures which were later of real benefit to the entire industry.

Professor Hart had the ability to convince industry that the facts must be obtained and their procedures modified to fit the facts.

Later when the use of fluorine in drinking water was suggested as a means of controlling dental caries, Professor Hart was frequently called upon as an advisor and consultant in this program. As late as January, 1952 he testified before the House Select Committee to Investigate the Use of Chemicals in Foods and Cosmetics (82nd Congress) on the possible deleterious effects of fluorine. His advice at this time was typical, namely, that more extensive studies should be carried out before far-reaching conclusions could be made. Perhaps he was overly cautious in opposing the rapid application of this procedure but his opposition was based on sound knowledge of the dangers inherent in such a program. In fact the very day before his death he was called upon for advice regarding the addition of fluorine to the drinking water in the city of Milwaukee.

He was frequently called upon for advice, but his response was always the same—secure the needed facts through research. In fact it was a question of this kind which led him to demonstrate that urea could be used as a source of nitrogen in ruminants. An industrial concern came to him with experimental data that had been reported in Germany indicating that simple forms of nitrogen might be used as a replacement for part of the protein in the diet. He searched the literature and found that every bit of evidence indicated that this was not true. However, he was not satisfied with the available facts and went to the dairy barns to get a few cows in order to set up an experiment on urea. He soon demonstrated that under proper conditions, urea can be used by ruminants and as a result of these studies urea is used in a practical way today. After this discovery he willingly gave his time to answer problems arising as a result of adding urea to animal feeds, whether the inquiry came from an industrial company manufacturing urea or from individual farmers who might have difficulties.

Professor Hart's interest in minerals and their relation to nutrition also led him into the field of food technology. In the manufacture of condensed milk, the sterilization process involves heating the milk at a fairly high temperature for a considerable length of time. During this sterilization process

the milk often coagulates and even if the coagulum is broken up by shaking, the product is not accepted by the consuming public. Hart, together with Dr. H. H. Sommer, showed that the main factor in the heat coagulation of milk is dependent upon the composition of milk salts. They showed that this difficulty could be remedied on a commercial scale by the addition of the proper amount of sodium citrate or disodium phosphate. This observation eliminated the difficulty of coagulation and the industry still uses this procedure.

Although Hart worked in the vitamin field most of his life his achievements present a peculiar anomaly. It is doubtful that we can associate Hart's name with the discovery of a specific vitamin or the isolation of a new vitamin. In this respect his experiences paralleled those of Sir Jack Drummond who though active in the vitamin field for more than a quarter of a century has no vitamin linked to his name. Such are the unpredictable rewards of fickle fortune. However, he had a hand in studies on every one of the known vitamins. It is told that he was instrumental in helping Dr. McCollum differentiate vitamin A from vitamin B, because he felt that McCollum was spending too much money for the purchase of the sugar—lactose. In the early studies McCollum used as part of the ration for his experimental animals the milk sugar lactose, but it was rather expensive and Professor Hart suggested that he use a cheaper form of carbohydrate. When this was done the ration was not only deficient in vitamin A, but also deficient in the water soluble vitamin complex. The reason for this was the fact that lactose as manufactured in those early days carried with it considerable quantities of B vitamins which were present in the original milk. Hart was associated with Steenbock and others in studies on the chemical properties of the antiscorbutic vitamin or vitamin C. He was associated with Steenbock in the early work on vitamin A and especially on the antirachitic vitamin which Dr. Steenbock later showed could be produced by exposure of foods to ultra-violet light. His interest in vitamin D was stimulated largely by the difficulty which poultry raisers were encountering in attempting to produce chicks for broilers through indoor feed-

ing. When they were reared indoors the chicks did not grow and their legs became deformed. The condition was known as leg weakness. This deficiency was shown to be due to a lack of Vitamin D and as a result of this work the broiler industry was saved.

He was associated with many of the studies dealing with the B vitamins. In many cases other members of his staff took the initiative in these studies, but he was genuinely interested in the progress of each study. Nothing thrilled him more than to see a new fact thoroughly established and he was pleased when a member of his staff made these new and fundamental discoveries. Frequently he was critical of new techniques, especially if they required elaborate equipment, but as soon as he saw results from these new techniques he was as enthusiastic over the new procedure as any one else. He was always helpful to the many students who frequently came to him for advice. Often he went to the literature to find helpful hints for investigators regardless of whether they were working directly with him or with some of his colleagues. A total of 46 students received their Ph.D. degrees under Professor Hart, but he was helpful to at least three times this number of students. The following acknowledgment in a Ph.D. thesis presented shortly after Hart's death is typical of the high regard which all the students had for him. "His very presence in the laboratory and the inspiration of his personality, no less than the positive encouragement he was ever ready to supply, have been the writer's most richly rewarding experience of the years during which the work reported here was in progress." He recognized the importance of cooperation in research work and he not only carried out this cooperation personally but encouraged other members of his staff to do likewise.

Professor Hart's pleasing voice and affable manner made him an effective public speaker both to scientific and lay audiences. He was frequently called upon to give public addresses but he turned down a very large percentage of the invitations. He realized that he could not give a good lecture without proper preparation and he never failed to take the

necessary time for such preparation. Whenever he did accept a speaking engagement he would immediately proceed to work on his manuscript. Often he would have his paper ready months before the time of delivery.

He had great personal charm and a keen sense of humor which made him a delightful companion. He belonged to a dinner club in Madison for many years; he always presented his latest research findings to this group but he was equally interested in reports made by other members of the club. He had the ability to present the most difficult results in simple and understandable words. He tried to instill this ability in his students and was often critical when students handed him reports which were poorly prepared.

He was a member of the American Society of Biological Chemists and a charter member of the American Institute of Nutrition. He also held membership in the American Association for the Advancement of Science, the American Chemical Society, the Society for Animal Production, and the American Dairy Association. He was a member of Alpha Chi Sigma, Alpha Zeta, Phi Lambda Upsilon, Sigma Xi, Phi Kappa Phi and an honorary member of Phi Beta Kappa.

He received several professional awards and honors, among which were the Borden award from the American Dairy Association in 1941 and the honorary degree of Doctor of Science from the University of Wisconsin in 1949. He was elected to the National Academy of Sciences in 1944, an honor which he highly treasured but unfortunately he never attended a meeting of the Academy. He did not enjoy meetings and when he did go to the national meetings one or two baseball games were usually included in the itinerary. His failure to attend scientific meetings was unfortunate because he had much to contribute and many would have liked to become better acquainted with him.

On May 15, 1931 the members of his department gave a dinner in his honor and presented him with bound volumes of his papers. This was given in commemoration of his 25 years of service as leader in research and as chairman of the Department of Agricultural Chemistry. At the time of his

official retirement in 1945 his friends and colleagues gave him another dinner which was attended by several hundred people. At this time a portrait painted by Mr. C. W. Thwaites was unveiled and has been hung in the library of the Department of Biochemistry.

It took persuasion by several members of his department before he agreed to a dinner in his honor. However, he thoroughly enjoyed the experience and his comments at the end of the program were the highlight of the evening. His final words included the following: "Science and research thus breathe the very air of freedom and offer in a day of peril and confusion, a mighty reinforcement to the free spirit of man. By bitter trial we have learned at last that this free spirit is no natural gift but must be nourished and defended or it will be lost."

While Professor Hart did not like honors or special recognition it is interesting that he went out of his way to pay special tribute to Dr. Babcock, who preceded him. A few years ago when the Babcock award was given by the food technologists in Chicago he had agreed to talk on the life of Dr. Babcock. A few weeks before the scheduled program he was stricken with a very severe case of arthritis. In spite of this great physical handicap he was determined to proceed to Chicago to give his paper. It was only after much persuasion that he agreed to have someone else present the paper which he had written.

At this point it is interesting to relate the final outcome of this attack of arthritis. It was in May, 1950, that Hart began to suffer from sciatica. He consulted orthopedic surgeons, physical therapists and many others, but there was no improvement during a period of three months. X-rays indicated the presence of lime deposits in the lower lumbar region as the cause of the severe pain. Hart, therefore, went back to his early experiments with animals and wondered if it would be possible to remove the calcium deposits by producing an acidosis. In other words he made himself an experimental guinea pig. Instead of using hydrochloric acid, he decided to

use ammonium chloride because a larger quantity of chlorine could be ingested through the use of this compound. He took four grams of the ammonium chloride daily, two after the morning meal and two after the evening meal. He followed this treatment for three weeks and at the end of this period he found that the pain had left, he could walk normally and there was no reoccurrence of the trouble. He realized that his own case was complicated by the use of diathermy and massage during the period that he took ammonium chloride. However his improvement was much greater during the period of ammonium chloride treatment than at any other stage. This stimulated his interest in the entire field of arthritis and during the last few years he gave much of his time to study and research on this problem. Many of his friends and total strangers wrote to him for the procedure which he used. Several individuals who tried his treatment encountered distinct improvement while others, of course, failed to find much relief.

When students returned to the Wisconsin campus, they went directly to Professor Hart's office for a visit. He was anxious to see every one of them and ask after their progress, and often gave them helpful advice that they could use when they went back to their own laboratories. After his retirement he had even more time to give to visitors whether they were his students or distinguished scientists from other parts of the world. During his active career he was more abrupt and often would tell the student or visitor that he had no more time to give at present but that they could come back at some later time. This was especially true if you came to his office shortly before a scheduled lecture. When you sat in his lecture it would appear that he was so thoroughly familiar with his subject that he needed no notes or no frequent consultation of the literature. However, he rarely gave a lecture without reviewing his notes and developing the proper mood for a stimulating talk.

He was an outstanding teacher. As a lecturer he was pleasing, clear, and stimulating. He was a skillful and search-

ing quiz master, immediately detecting superficial knowledge and impatient of it. In addition to the course in dairy chemistry mentioned earlier, he gave the general or elementary course in agricultural chemistry, later biochemistry. In this course he had sophomores, juniors, seniors, and often graduate students. His questions would be tempered to the level of training of the student. Nothing would please him more than to find a graduate student in his elementary course who could not answer a simple question readily answered by a sophomore. His evaluation of a student was based largely on personal contact with the student. He usually went through the formal action of giving examinations but often he would use the same questions year after year. He would diligently read the examination papers but often the grades would not necessarily depend upon the results of the examination.

Usually he had another member of the staff in charge of the laboratory part of his course but he visited the laboratory section daily. In fact, he often visited the laboratory sections in courses with which he had no connection. For many years Professor W. H. Peterson gave the other elementary course in the department which was given largely for home economics girls. Hart would delight in visiting the laboratory in this course and asking the girls what they were doing. Usually he received intelligent answers but one day one of the girls turned to him and said "I don't have to answer questions asked by the janitor." The reason for this reaction was undoubtedly due to the fact that he seldom wore a laboratory jacket in the laboratory but would generally take his coat off and use a small piece of toweling or cheese cloth as an apron. This apron was not changed too frequently and often he did look like a janitor. No one enjoyed this reply more than Professor Hart and he frequently told the story on himself. When a younger member of the staff took over his elementary course Professor Hart agreed, after many requests, to give an advanced course in nutrition. Students from all over the campus took this course and the discussions included many areas outside the field of nutrition. He would completely lose

himself during the discussions and often the class would not be dismissed until 30 or 45 minutes after the scheduled time for the class to close. In addition to his formal teaching he also conducted a general seminar which was equally stimulating to everyone who sat in it.

In addition to his research and teaching he was a successful administrator. He took over as chairman of the department when he arrived in 1906 and continued until 1944. In the early days his department was small, for many years not more than 4 members, there were no staff meetings and usually he made the necessary decisions with little consultation with the staff. However, as the department grew larger he reluctantly accepted the procedure of having staff meetings although they were held as infrequently as possible and usually they were dismissed as rapidly as possible. He recognized that administrative procedure was necessary but that it took time from both teaching and research. He rebelled against unnecessary reports but agreed to do those which were absolutely necessary and prepared them in concise form and always had them ready on time. He was impatient when special problems and issues arose and he would try to settle them as rapidly as possible. In doing so he would often act without making the necessary inquiries and he would not hesitate to make arbitrary decisions which might be distasteful to his colleagues. When he first gave the elementary course in agricultural chemistry he included material dealing with soils and bacteriology. When the professors giving related courses questioned the wisdom of this he immediately replied that he was teaching agricultural chemistry and it was none of their business what he included in the course.

During his early years at Wisconsin and shortly after Dr. McCollum came to the department from Yale University, Dr. L. B. Mendel expressed some annoyance over the fact that the nutritional studies at Wisconsin were being conducted along somewhat similar lines to those being carried on at Yale. Hart took little time in answering this criticism in direct fashion and pointed out that there was no economic waste for

two laboratories to engage in similar lines of work since thereby the viewpoints are widened and the conclusions strengthened. While these curt answers often irritated his colleagues, those who knew him well realized that these rapid actions were made so that he would have more freedom for research work.

As an administrator he worked hard to keep his staff intact. There were few losses of personnel from his department over the 38 years that he served as its head. He expected much from his associates but he never attempted to direct their work or to indicate what problems they should study. He was anxious to cooperate with workers in other departments and encouraged his staff to do the same. In fact, it was his successful cooperation with the workers in many departments that has done much to break down the departmental barriers at the University of Wisconsin.

Professor Hart served on relatively few University committees although he was an efficient committee member and worked very hard on the appointments which he accepted. One of his most enjoyable and fruitful activities was his service on the Research Committee of the Graduate School. This committee was organized in 1919 to help stimulate research in the University and later this committee served to make grants to faculty members for research. He was an original member of this committee and served on the committee for a period of 19 years. He was greatly disappointed when President Glenn Frank came to the University of Wisconsin and failed to appoint him to this committee. However, he was reappointed in later years and during the year 1944-45 he served as its chairman. He maintained high standards in research and was not afraid to tell his colleagues that projects which they submitted did not appear to be of the quality necessary for support from the Research Committee. However, he was equally enthusiastic about good projects and would go out of his way to compliment faculty members or students who had shown real progress in their work. Some of the money dispensed by the Research Committee became

available through the Wisconsin Alumni Research Foundation. This was established to develop the discovery made by Dr. Steenbock that ultraviolet light would produce vitamin D. Professor Hart believed that income from research findings should if possible be used to support further research. He turned several of his discoveries over to the Wisconsin Alumni Research Foundation for development and he was enthusiastic about using the income from these findings for further support of research.

In 1903 Professor Hart married Annie Virginia DeMille. For many years the Harts together with their one daughter, Margaret, lived within two blocks of the laboratory. This location was very convenient since he visited the laboratory on Sundays as well as on week days. The family did not take part in many social activities but it was a privilege to visit in their home and to be included in their small dinner parties. For many summers the Hart family proceeded to the tip of Door County in Wisconsin where they had a cottage on Green Bay just outside the village of Ellison Bay. There were few conveniences in the cottage and during the summer they lived a primitive life. Professor Hart enjoyed sailing on the bay and swimming, as well as playing tennis on the court adjacent to his cabin. Mrs. Hart died June 28, 1936, but Margaret, together with her husband, Professor Russell Larson, lived with him in the family home. During the more recent years he and his daughter and son-in-law enjoyed Christmas trips to Mexico, Central America, South America and Hawaii. He was fond of sports both as a spectator and as a participant. He skated and played tennis even in the later years of life, but made his sports recreation and not work.

On March 11, 1953 Professor Hart came to the laboratory as usual. Although he had been officially retired for almost 8 years he visited the laboratory daily and continued his interest in all activities in the department. He left the laboratory about 4 o'clock in the afternoon and spent an unusually pleasant evening with his family at home. During the night he was stricken with a coronary attack and died on March 12, 1953.

If one were to write a complete story of Professor Hart's life it would involve writing a complete history of nutrition during the first 50 years of this century. However, much of his work can be traced in the publications listed in the bibliography which follows. His life was exceptionally rich in outstanding achievements and great leadership and in kindly inspiration to those who had the good fortune of knowing him.

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

- Amer. Chem. Jour. = American Chemical Journal
 Amer. Jour. Physiol. = American Journal of Physiology
 Amer. Jour. Pub. Health = American Journal of Public Health
 Ann. Rev. Biochem. = Annual Review of Biochemistry
 Arch. Biochem. = Archives of Biochemistry
 Biochem. Jour. = Biochemical Journal
 Jour. Agr. Res. = Journal of Agricultural Research
 Jour. Amer. Chem. Soc. = Journal of the American Chemical Society
 Jour. Amer. Diet. Assoc. = Journal of the American Dietetic Association
 Jour. Amer. Vet. Med. Assoc. = Journal of the American Veterinary Medical Association
 Jour. Assoc. Off. Agri. Chem. = Journal of the Association of Official Agricultural Chemists
 Jour. Biol. Chem. = Journal of Biological Chemistry
 Jour. Dairy Sci. = Journal of Dairy Science
 Jour. Exp. Med. = Journal of Experimental Medicine
 Jour. Nutr. = Journal of Nutrition
 Jour. Ped. = Journal of Pediatrics
 N. Y. Agri. Exp. Sta. Bull. = New York Agricultural Experiment Station Bulletin
 Poultry Sci. = Poultry Science
 Proc. Amer. Soc. Animal Prod. = Proceedings of the American Society of Animal Production
 Proc. Soc. Exp. Biol. Med. = Proceedings of the Society for Experimental Biology and Medicine
 Soil Sci. = Soil Science
 U.S. Dept. Agri. Bur. An. Ind. Bull. = United States Department of Agriculture, Bureau of Animal Industry Bulletin
 Univ. Wis. Agri. Exp. Sta. Res. Bull. = The University of Wisconsin Agricultural Experiment Station Research Bulletin
 Univ. Wis. Agri. Exp. Sta. Cir. Inform. = The University of Wisconsin Agricultural Experiment Station Circular of Information
 Wis. Agri. Exp. Sta. Bull. = Wisconsin Agricultural Experiment Station Bulletin
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1863-1951

BY PAUL R. CANNON

The principles which guided the scientific life of Ludvig Hektoen over an active professional career of more than sixty years are clearly pointed out in a paper published by him in 1904. This was shortly after he had become Head of the Department of Pathology of the University of Chicago and Director of the John McCormick Institute for Infectious Diseases. In that paper Hektoen suggested that, inasmuch as pathology is, in fact, pathologic biology, it should be studied as a part of general biology, with no particular reference to its practical applications. Moreover, he suggested that "there are other modes of progress toward knowledge of cellular activity and biologic mechanisms under pathologic as well as normal conditions than the purely morphologic highway." Thus, "in certain fields, at least, the student of the pure science of disease is primarily interested in the knowledge of disease for its own sake without much thought or immediate care as to any prompt, practical use to which such additions as he may make to this knowledge may be put. It is true here, as it is in general, that most things are done only on account of the results expected from them in the future, but immediate technical utility is not always the sole guiding principle of the investigator in pathologic domains. The history of pathology shows him that in this science, as well as in its synthetic sciences, all actual increase in knowledge eventually helps to relieve suffering."

Almost four decades later, in an evaluation of his career, Dr. James P. Simonds remarked that when Dr. Hektoen entered pathology "its intellectual atmosphere was already becoming sultry and oppressive with the stagnant air of decadence and ineffectiveness. Most of the contributions to pathologic anatomy had become trivial because they were merely repetitions and added little that was either fundamental or new." In short, the pathology of those days had to await developments in the fields of physiology and biochemistry before it would become possible

to interpret structural changes induced in the body by disease in relation to mechanisms of disease. As Simonds further said, Hektoen's mind was too active and too incorrigibly speculative to be content with descriptive methods alone. It was inevitable, therefore, that he should take the dynamic approach to the problems of infection and immunity, and "by so doing he was able to make the numerous useful and practical as well as the fundamentally scientific contributions to medicine."

Many of these contributions are now themselves a part of the history of medicine for which Hektoen himself had such a great respect. While making them he also helped by precept and example to establish traditions in pathology which will serve as guides to other pathologists in the years to come. Throughout his long and active life Dr. Hektoen demonstrated the cumulative value of such attributes as persistence, sustained industry, the intelligent application of simple methods to specific problems, a meticulous devotion to duty and a life-long enthusiasm for his chosen fields of interest. Because of these and other qualities his contributions to the history and traditions of pathology and medicine will long command the emulation and respect which they so well deserve.

School and College

Ludvig Hektoen was born in Westby, Wisconsin, on July 2, 1863, the son of Peter P. and Olave (nee Thorsgaard) Hektoen. Peter Hektoen was a Lutheran parochial school teacher and farmer, and Ludvig's early years were those of a farm boy in a Norwegian community in which English was spoken only in school. At the age of thirteen he entered the Monona Academy in Madison, Wisconsin. The following year he enrolled in Luther College at Decorah, Iowa, where he spent the next six years, graduating with a B.A. degree in 1883. At Luther College he received a general education in Latin, Greek and mathematics, with no training in science. He took advantage of the library facilities and was a member of the debating society, but there was nothing in his course of training which might have been expected to point him toward a medical career. However, about two years before his graduation, during his

vacation periods, he became acquainted with a young Norwegian physician, Johan K. Schreiner, who had entered the practice of medicine in Westby. Presumably Dr. Schreiner was an inspiration to the young college student, for, following graduation, Hektoen spent a year at the University of Wisconsin taking premedical courses in biology, histology and chemistry. Upon completion of this work, he entered the College of Physicians and Surgeons in Chicago.

Medical School and Early Professional Appointments

He began his medical work in the fall of 1885 and received his M.D. degree three years later. It is noteworthy that he was the class valedictorian. He passed the examination for an internship in the Cook County Hospital, winning first place in this competition, and spent the next two years there. At this time he also came under the influence of another physician who did much to mould his professional career. This was Christian Fenger. Following his internship in 1889 he was appointed as pathologist to the Cook County Hospital, a position in which he served until 1903. In 1889 he was also made curator of the museum of Rush Medical College, and, in 1890 physician to the Coroner's Office of Cook County, and Lecturer in Pathology at Rush Medical College. From 1892 to 1894 he was Professor of Pathology at the College of Physicians and Surgeons, returning to Rush Medical College as Professor of Morbid Anatomy in 1895. In these years between 1890 and 1895 he also studied abroad, in Upsala, Prague and Berlin.

Professional Career as a Leader in Medicine

In 1898 Hektoen became Professor of Pathology at Rush Medical College, and in 1901, Professor and Head of the Department of Pathology at the University of Chicago. He served in these two capacities until 1932 and 1933, when he became Professor Emeritus.

During his long professional career Dr. Hektoen revealed an extraordinary array of attributes as a pathologist, medical scientist, writer, teacher and administrator. His leadership in these areas was manifested in many ways. From 1898 to 1902 he

served as President of the Chicago Pathological Society. In 1901 he was President of the American Association of Pathologists and Bacteriologists. Other Presidencies included: Chicago Medical Society, 1919-1921; Society of American Bacteriologists, 1929; American Society of Immunologists, 1927. He was a founder of the Institute of Medicine of Chicago in 1915, and was chairman of its board of governors from 1921 to 1940. He served as chairman of the Division of the Medical Sciences of the National Research Council in 1924, and again in 1926 and 1929. From 1936 to 1938 he was also Chairman of the National Research Council. In the American Medical Association he was chairman of the Section on Pathology and Bacteriology in 1900 and 1901 and was a member of the House of Delegates in 1918 and in 1920. He served the United States Public Health Service from 1934 to 1938 as a member of the National Advisory Health Council, and from 1937 to 1944 as executive director of the National Advisory Cancer Council. In 1930 he became chairman of the Cancer Research Institute of Chicago. He was also one of the founders of the Chicago Tumor Institute, and was president of its board of trustees until 1951.

The following paragraphs, quoted, with a few minor changes, from an article prepared by the writer in an attempt to evaluate the significance of Hektoen's work as a medical scientist, give an indication of his contributions to medical science.

"An evaluation of his scientific career over its more than 60 years of significant contributions to medical science requires an appraisal of its influence both on the development of medical knowledge and on the promotion of human welfare. Fortunately, the task is made less difficult by the fact that his career is represented by a record of sustained achievement seldom equaled. Throughout, it is characterized by a great diversity of interests and a wide range of contributions to medical science and practice. In the record of more than 300 publications one can discern the methods and intellectual traits of an unusual man, many of whose investigations now stand out as landmarks in the history of medicine.

"In attempting to evaluate these publications as a whole it is noteworthy that of the first hundred, ending in 1903 with *An*

Anatomical Study of a Short-Limbed Dwarf, almost all were brief case studies of a type such as any young pathologist might be expected to engage in during his earlier professional years. At this time Hektoen was 40 years of age. One exception is a paper, *The Vascular Changes of Tuberculous Meningitis, Especially the Tuberculous Endarteritis*, embodying material collected during time spent in the laboratory of Chiari. This study was the result of an effort to elucidate the pathogenesis of tuberculous meningitis, and the endarterial changes were interpreted as pointing to the hematogenous origin of the meningitis. Another exception to be noted pertains to his studies of some of the fungal infections, particularly actinomycosis, blastomycosis, and sporotrichosis. Nevertheless, inspection of these first hundred publications affords little evidence of the direction of the path which Hektoen was to tread during the next five decades.

"As already noted, in 1901 he became professor and head of the department of pathology and bacteriology at the University of Chicago, and in the following year, director of the newly formed John McCormick Institute of Infectious Diseases. Soon thereafter his scientific communications began to indicate more clearly his interest in a variety of problems related to the subjects of infection and immunity.

"In this review an attempt will be made to summarize only his more important contributions in the latter field. In doing so, no attempt will be made to enter into a discussion of priorities with respect to any particular subject; rather emphasis will be placed mainly on the significance of these researches in their relationship to the enlarging knowledge of immunology and infectious diseases.

"It was between the years 1903 and 1937, in particular, that his most important investigations were carried on. Prominent in all of them, in one way or another, is the problem of antibodies. During this period his active mind led him into many aspects of immune-body reactions, including their nature, sites of formation, modes of action, especially in the animal body, and their usefulness as tools for the elucidation of many perplexing problems of biology and medicine. As early as 1907, for ex-

ample, we find him concerned with the phenomena of isoagglutination and blood-group reactions. At that time he pointed out that 'the common occurrence of isoagglutinins in human serum suggests that under certain special conditions homologous transfusions might prove dangerous by leading to erythrocytic agglutination within the vessels of the subject transfused.' In the present age of blood banks and blood-typing routines it is interesting to note his emphasis on the need for proper blood typing and his cautious acceptance of the seemingly practical possibilities of the new procedure of blood transfusions! Soon his name became more and more associated with the subject of antibody mechanisms, and by 1910 he was asked to give a Harvey Lecture. This he did, discussing the question of *The Formation and Fate of Antibodies*.

"In those early years, just as now, there was much confusion concerning the nature of antibody action. However, there can be no doubt that some of this confusion was lessened materially by Hektoen and his associates. For example, by 1910 he had pointed out the necessity of considering the 'antibody curve' as a whole in any study of antibody action, and he had warned against the fallacy of drawing conclusions from a single point on this curve. Even today failure to follow this basic principle continues to add confusion to the immunological literature. It is noteworthy, also, that Hektoen regarded the antibody curve as an indication of 'the balance between production and loss of antibody,' thus evidencing his appreciation of the dynamics of antibody action. By this time he had also become interested in the fact that 'in animals previously subjected to the action of a certain antigen the mechanism of antibody production may be especially sensitive to that antigen and respond to proper doses more promptly and freely than is the case in fresh animals.' This will be alluded to in more detail later. His work with Carlson demonstrated that antigen injected intravenously into dogs is removed from the blood within from 3 to 48 hours, thus indicating that antibodies are produced outside the blood circulation, and that blood itself does not 'fix' antigen. He also found that splenectomy just before or just after injection of antigen led to a lower but otherwise

typical antibody curve. Later he studied the question of sites of antibody formation by the ablation of different organs prior to or coincident with antigenic stimulation and found that removal of the stomach, the small intestine, or the thyroid gland caused no interference with antibody formation, nor did adrenalectomy or removal of one-half of the liver. From these and other studies he concluded that 'the mechanisms for the fabrication of antibodies are quite secure from certain disturbances, and they are in no way contradictory of the current view that these mechanisms are located in the blood-forming organs.'

"Between the years 1915 and 1922 appeared his important studies dealing with the effects of leucotoxic agents on antibody formation, including x-rays, thorium x, radium emanation, benzene, toluene, and mustard gas. These studies later proved to be especially valuable following the development of the atomic bomb, and in relation to current investigations of radiation injury. In them he observed a marked reduction in output of antibodies after x-radiation provided that the raying was done several days before the injection of antigen and that it was continued during the period of antibody production. He correlated these findings with the observed facts of a greatly reduced volume of splenic, lymphatic, and thymic tissue, together with changes in the bone marrow, and concluded that his observations harmonized with the view that antibodies are produced in the spleen, the lymphatic tissues, and the bone marrow. He remarked that 'the results indicate also that one reason why the lymphocyte appears to be an important agent of defense in tuberculosis and other conditions may be its power to form antibodies.' Such chemicals as benzene, toluene, and mustard gas also gave a reduction in the production of certain antibodies, associated with grave lesions in the bone marrow and with leucopenia.

"In 1917 he recorded a puzzling observation under the title *Precipitin-Production in Allergic Rabbits*. While attempting to produce precipitins to horse protein in rabbits he observed that 'the introduction of horse blood or serum in rabbits treated a considerable time previously with sheep blood resulted in the

production not only of precipitin for horse protein, but also for sheep protein, as well as for proteins of several other species.' As he emphasized, 'the particular point on which special stress is placed now is the capacity of the rabbit under suitable conditions . . . to elaborate different precipitins at the same time. It appears that the precipitin-production induced in the usual way leaves behind it an increased power of further production so that large amounts of major as well as group and minor precipitins are elaborated on the injection of a new serum or blood. Manifestly the phenomenon is an expression of an increased reactivity and may be classed with other manifestations of allergy.' This independent observation of what is now known as the anamnestic reaction, aside from its theoretical interest, was seen, also, in its practical implications when he suggested that the reappearance of typhoid agglutinins under the stimulation of other infections could be expected to nullify the significance of the Widal test as a method for the diagnosis of typhoid. He thought of this phenomenon as a 'reawakening' of a latent capacity to elaborate specific antibody and pointed to the hazards of such an effect in medicolegal work unless fresh rabbits were used in each instance. Later, with Boor and others, he demonstrated that rabbits receiving simultaneous injections of 35 purified proteins fabricated specific antibodies simultaneously for at least 34 of the 35 antigens injected. Furthermore, when rabbits were immunized against many antigens, the injection later of one of the antigens usually caused the precipitin for that antigen alone to disappear from the blood, indicating that in the rabbit 'different precipitins exist as separate entities.' He also showed in rabbits in which multiple precipitins had been formed after multiple injections of antigen that at a time when they were no longer demonstrable in the blood many might reappear on the injection of only one of the antigens previously injected.

"Hektoen does not seem to have been especially interested in methods, and in much of his work he utilized only the conventional antigen-dilution variety of precipitin test. Today this method is looked on as essentially semiquantitative; indeed, by some, it is regarded as an outmoded serological procedure.

Nevertheless, it is remarkable how many complex aspects of immunology he was able to clarify by intelligently applying this comparatively simple method to the solution of specific problems. With it, for example, Hektoen studied such problems as the antigenic components of hemoglobin, of lens protein, of semen, Bence Jones protein, serum proteins, extracts of various animal parasites, thyroglobulin, fibrinogen, egg white, muscle hemoglobin, etc. He was a firm believer in the view advanced by Osborne and Wells of the importance in immunological research of employing purified proteins whenever possible. Associated with him in these studies should be mentioned in particular Welker, Cole, Schulhoff, Whipple, and Robschey-Robbins. In the studies of lens protein he found a consistent organ-specificness for different species, as he found also in his studies of mammalian thyroglobulins, fibrinogen, and casein. In contrast he observed that solutions of skeletal muscle from the dog were precipitinogenically distinct from those of hemoglobin from dog blood. Of medicolegal significance was his finding that precipitins to human seminal proteins were specific and that this method, therefore, was valuable for the detection of suspected seminal spots and stains, as was the precipitin test for hemoglobin a specific test for blood only. With Welker he concluded that precipitins for several of the blood proteins were individually as well as species distinct, that each protein exists as an independent antigenic unit in the blood or serum and that its antigenic individuality is not the artificial product of the process of separation. With Cole he found that egg white contains five distinct antigens, one of which, conalbumin, was immunologically identical with blood albumin.

"Despite his lack of concern for methodology as such, it is important to note that the method developed by Hektoen and Welker for the sustained production of antibodies has been widely used since it was published in 1933. At that time Hektoen was 70 years of age. This method consisted in the antigen's being adsorbed to aluminum hydroxide prior to its intramuscular injection. They reported that 'in rabbits a single intramuscular injection of aluminum hydroxide carrying a measured quantity of antigen may induce continuous formation

of precipitin for many months' and that 'antigens adsorbed on aluminum hydroxide do not separate on standing and retain their precipitinogenic properties for at least 12 months and probably much longer.' By this method it was shown that at least 10 distinct specific antigens may be adsorbed at the same time and such an injected gel will engender the production of 10 specific antibodies.

"Besides his continuing interest in basic problems of immunology, Hektoen was also interested in the pathogenesis of measles, and as early as 1905 he had produced the disease experimentally in human subjects by the subcutaneous injection of blood from a measles patient, thus demonstrating that the virus may be in the blood at least during the first 30 hours of the rash. In 1911, with Eggers, he also reported the production of measles in rhesus monkeys by injection of citrated measles blood. He maintained a keen interest, also, in the problem of scarlet fever, and contributed to the studies of Tunncliffe, and of George F. and Gladys Henry Dick, in their significant contributions to the better understanding, control, and treatment of this disease. He was also a pioneer contributor to our knowledge of coronary thrombosis and performed the necropsy on a patient reported on by Herrick in 1912. In this patient Hektoen described the presence of a red thrombus which had completely occluded the sclerotic left coronary artery, accompanied by severe myocardial infarction and a nonbacterial fibrinous pericarditis."

Career as a Medical Writer and Editor

In addition to his activities as a pathologist and medical scientist Hektoen early demonstrated unusual abilities as a medical writer and editor. His clarity and conciseness of style, coupled with a meticulous accuracy, soon brought to him increasing duties in this field. In 1904 he became editor of the *Journal of Infectious Diseases*, serving in this capacity until 1941. In 1926 he also became editor of the *Archives of Pathology*, and performed the exacting duties of this assignment until 1950. For many years he edited both the *Transactions of the Chicago Pathological Society* and the *Proceedings of the*

Institute of Medicine of Chicago. For over forty years he also served as editorial writer for the *Journal of the American Medical Association*. In 1894 he wrote a book on Postmortem Technique, and in 1902 he was coeditor of the American Textbook of Pathology. In 1927 he wrote the Introduction to the Study of Infectious Diseases for the third edition of *Modern Medicine: Its Theory and Practice*, by W. Osler and T. McCrae. He also edited Dürck's *Pathological Histology* (1904), *Contributions to Medical Science* (H. T. Ricketts) 1911, and the *Collected Works of Christian Fenger* (1913). With Miss Ella Salmonsens of the John Crerar Library he was co-compiler of the *Bibliography of Infantile Paralysis* (1789-1944). This was published in 1946.

Honors and Lectureships

He received many honors, including eight honorary degrees. These were:

M.D.	Christiania University, Norway	1911
Sc.D.	University of Michigan	1913
Sc.D.	University of Wisconsin	1916
LL.D.	University of Cincinnati	1920
LL.D.	Western Reserve University	1929
LL.D.	Luther College	1936
Sc.D.	University of Illinois	1940
LL.D.	University of Chicago	1940

In 1918 he was elected to the National Academy of Sciences; in 1929 he was given the Order of St. Olaf by the Norwegian Government; in 1941, the Centennial Award of the Wisconsin State Medical Society; and in 1942 the Distinguished Service Medal by the American Medical Association. In this year he was also presented with the Gold-Headed Cane by the American Association of Pathologists and Bacteriologists. In 1949 he was given the Ricketts Award by the University of Chicago.

He was honored with numerous lectureships, including the Harvey and Herter Lectures in New York City, the Cutter Lecture in Boston, the Harrington Lecture in Buffalo, and the Pasteur and Fenger Lectures in Chicago.

He was an honorary member of the following organizations:

Philadelphia Pathological Society
 Academy of Medicine of Washington, D.C.
 Norwegian Academy of Science
 Norwegian Pathological Society
 Norwegian Medical Society
 Swedish Medical Society
 American Society of Clinical Pathologists
 New York Pathological Society
 College of American Pathologists

The John McCormick Institute For Infectious Diseases

In 1902 Hektoen became Director of the John McCormick Institute for Infectious Diseases. This Institute was established on January 2 of that year by Harold Fowler McCormick and Edith Rockefeller McCormick in memory of their son, John, who had died of scarlet fever. It was developed "for the study and treatment of scarlet fever and other acute infectious diseases and the investigation of allied problems," with the further objective of advancing the "knowledge of infectious diseases in order to improve the methods of prevention and cure and also to care for patients suffering from certain common, acute, infectious diseases." To this end the Durand Hospital was also added. It is perhaps an indication of Dr. Hektoen's administrative acumen that, in describing the work to be carried on, he noted that "persons who give promise of making good use of the opportunity may be appointed as volunteer workers. Ordinarily, regular full-time appointments on the staff with stipend are made only as vacancies occur." In the Institute and the Durand Hospital was carried on the work of Doctors George F. Dick and Gladys Henry Dick which did so much to elucidate the cause of scarlet fever. Moreover, here they also developed the Dick test to determine susceptibility to this disease, a method of immunization against it, and an antitoxin for its treatment. In the Institute worked, as students, many men and women who received inspiration and training from Hektoen and who made important contributions to medical science. A partial list of these workers is given in Fishbein's tribute to Dr. Hektoen. It

was a sad blow to Dr. Hektoen when, due to financial reverses starting in 1929, the Institute and the Durand Hospital had to be closed in 1939. Fortunately, both buildings are now actively functioning as the Hektoen Memorial Institute of the Cook County Hospital, and in them is an active group of investigators engaged in medical research.

Family, Personal Attributes and Avocations

On July 7, 1891, in Habo, Sweden, Dr. Hektoen married Ellen Strandh. The two children of this union, Aikyn, a daughter, and a son, Josef Ludvig, died tragically. Dr. Herrick, in reference to this said that Hektoen "was outwardly well poised and bore with astonishing stoicism the burdens of ordinary trouble. Only once . . . and this was when he referred to many tragic sorrows that had afflicted his family . . . did I hear his voice break and see him wipe the tear in his eye." Fishbein also said that he "withstood a buffeting in his personal life . . . such as has been the lot of but few men . . . (particularly the) tragedy in the death of his daughter and her children. . . . He met these tribulations with courage and with increased labor in his chosen fields."

Many of the personal qualities which endeared Dr. Hektoen to his friends and students have been alluded to in the tributes to him given by Morris Fishbein, James B. Herrick, Ernest E. Irons and H. Gideon Wells. The latter remarked that Hektoen as a teacher encouraged individuality, never trying to mould his students to a pattern or to impose his pattern upon them. On the contrary, he endeavored to have them develop their strongest and best qualities. With regard to his own associations with Dr. Hektoen, Wells said that "in the forty-two years of our relationship I have been to Hektoen innumerable times for aid or consolation, and never once have I failed to get the needed suggestion and encouragement, and always the advice has been wise, often with kindly salutary hints, so veiled as to carry the meaning without hurt." The others refer to his personal attributes in such terms as enthusiasm for medical reform, honesty and scientific accuracy, originality as an investigator, industry and indefatigability, modesty and idealism, kindliness of spirit,

inexhaustible patience, generosity, respect for history and tradition, systematic and orderly habits, conciseness, and keen sense of humor. These tributes become all the more meaningful in view of the tragedies already alluded to, as well as the severe financial reverses which forced the closing of the McCormick Institute. Through it all, however, he reacted with courage and equanimity and refused to become embittered. As Fishbein said, he was "the possessor of a calm gentility."

With so many obligations forcing themselves upon him, it is not surprising that he did not have much time for play or hobbies. He liked to read good books, and he evidently enjoyed some card games. Professor Anton J. Carlson tells of a trip home from the International Congress of Physiology, held in Stockholm in 1927, when he and Professor Wiggers played whist every day with Dr. and Mrs. Hektoen at one-tenth of a Swedish öre a point. When they landed in New York City, Carlson collected seven cents from the Hektoens. Dr. Hektoen also enjoyed golf. According to Fishbein, "I have never seen him manifest pride except after sinking an unusually long putt. I have never seen him inconsistent except in the difference between his golf drive when practicing and the motions that he uses when he actually hits the ball. These are sins that may well be pardoned."

His sense of orderliness is illustrated by his advice to laboratory workers that the laboratory should look as if no work is going on there. He also once said that a young investigator must be especially careful lest he find what he is looking for. His conciseness of expression and his sense of humor are seen in his reply to the gushy lady at the dinner party who said to him: "Dr. Hektoen, what important observations have you made this year?" His laconic answer was, "The skirts are shorter." As a young man his sense of humor included a preference for practical jokes, but, as Fishbein notes, these were invariably kindly.

Miscellaneous Activities

Finally, mention should be made of a few miscellaneous activities indicating Hektoen's further diversity of interests. For ex-

ample, as early as 1900 he was consulted frequently on medico-legal matters and soon enjoyed a considerable reputation as an expert in this field. His effectiveness was added to by the fact that while on the witness stand he was not afraid to say, "I do not know." In 1931 he was vice-president of the Chicago Academy of Criminology. In 1907 he was vice-president of Section K of the American Association for the Advancement of Science and in 1929, vice-president of Section N. For many years he was Chairman of the Committee on Scientific Research of the American Medical Association as well as Chairman of the Committee for the Scientific Exhibits. From 1908 to 1910 he was a member of the Illinois Committee to Investigate Diseases of Occupation. He also served for many years as a member of the Board of Directors of the Sprague Memorial Institute, the Chicago Institute of Psychoanalysis, the Elizabeth McCormick Fund, and the Board of Directors of the American Society for the Control of Cancer. During his later years he was active in the development of the John Crerar Library of Chicago and the Museum of Science and Industry.

Acknowledgements

The writing of this memoir was greatly facilitated because of the availability of the splendid biography written by Morris Fishbein commemorating Dr. Hektoen's seventy-fifth birthday. I have brought the bibliography up to date and have rearranged it by years. I have also drawn freely from the articles by Dr. James B. Herrick and Dr. James P. Simonds.

Although it is probable that some phases of Dr. Hektoen's active life have been omitted or inadequately evaluated, it is hoped that the facts here brought together may serve as a reminder of the many contributions made to pathology, to medicine and to human welfare by a man whose long life was characterized by beneficent actions and who was esteemed as a wise physician, a kindly counselor and an honored citizen.

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Ludvig Hektoen: A Study in Changing Scientific Interests, by James P. Simonds. The Proceedings of The Institute of Medicine of Chicago, 1942, 14:284-287

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KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

- Am. J. Dis. Child. = American Journal of Diseases of Children
 Am. J. Insan. = American Journal of Insanity
 Am. J. M. Sc. = American Journal of Medical Sciences
 Am. J. Obst. = American Journal of Obstetrics
 Am. J. Ophth. = American Journal of Ophthalmology
 Am. J. Physiol. = American Journal of Physiology
 Am. J. Pub. Health = American Journal of Public Health
 Arch. Path. = Archives of Pathology
 Biochem. J. = Biochemical Journal
 Biochem. Zeits. = Biochemische Zeitschrift
 Boston M. & S. J. = Boston Medical and Surgical Journal
 Boston Soc. M. Sc. = Boston Society of Medical Science
 Brit. J. Dermat. = British Journal of Dermatology
 Brit. M. J. = British Medical Journal
 Buffalo M. J. = Buffalo Medical Journal
 Bull. Alumni Assoc. Rush M. Coll. = Bulletin of the Alumni Association of Rush Medical College
 Bull. Am. Soc. Control Cancer = Bulletin of the American Society for the Control of Cancer
 Bull. Chicago M. Soc. = Bulletin of the Chicago Medical Society
 Bull. Soc. M. Hist. Chicago = Bulletin of the Society of Medical History of Chicago
 Centralbl. f. allg. Path. u. path. Anat. = Zentralblatt für allgemeine Pathologie und pathologische Anatomie
 Centralbl. f. Bakt. = Zentralblatt für Bakteriologie
 Chicago Clin. Rev. = Chicago Clinical Review
 Chicago M. Rec. = Chicago Medical Recorder
 Ill. Health News = Illinois Health News
 Ill. M. J. = Illinois Medical Journal
 Ind. M. J. = Indiana Medical Journal
 Internat. Clin. = International Clinics
 Internat. M. Mag. = International Medical Magazine
 J. Am. Chem. Soc. = Journal of the American Chemical Society
 J. A. M. A. = Journal of the American Medical Association
 J. Am. Pharm. Assoc. = Journal of the American Pharmaceutical Association
 J. Bact. = Journal of Bacteriology
 J. Exper. M. = Journal of Experimental Medicine
 J. Immunol. = Journal of Immunology
 J. Infect. Dis. = Journal of Infectious Diseases
 J. Lab. Clin. M. = Journal of Laboratory and Clinical Medicine
 J. M. Res. = Journal of Medical Research
 J. Mich. M. Soc. = Journal of the Michigan Medical Society
 J. Nerv. Ment. Dis. = Journal of Nervous and Mental Diseases

- J. Path. Bact. = Journal of Pathology and Bacteriology
 J. Prev. M. = Journal of Preventive Medicine
 M. News = Medical News
 M. Sent. = Medical Sentinel
 M. & S. Rep. Cook Co. Hosp. = Medical and Surgical Report of Cook County Hospital
 Minn. M. = Minnesota Medicine
 Nat. Bull. Am. Soc. Control Cancer = National Bulletin of the American Society for the Control of Cancer
 New Eng. J. M. = New England Journal of Medicine
 N. Y. M. J. = New York Medical Journal
 N. Am. Pract. = North American Practitioner
 Phila. M. J. = Philadelphia Medical Journal
 Phila. Mo. M. J. = Philadelphia Monthly Medical Journal
 Proc. Am. Sc. Cong. = Proceedings of the American Scientific Congress
 Proc. Ann. Cong. M. Ed. = Proceedings of the Annual Congress on Medical Education
 Proc. Inst. M. Chicago = Proceedings of the Institute of Medicine of Chicago
 Proc. Nat. Acad. Sc. = Proceedings of the National Academy of Sciences
 Proc. Soc. Exp. Biol. M. = Proceedings of the Society for Experimental Biology and Medicine
 Progr. M. = Progressive Medicine
 Pub. Health Mich. = Public Health of Michigan
 Quart. Bull. N.W. Univ. M. School = Quarterly Bulletin of the Northwestern University Medical School
 Studies & Rec. Norwegian-Am. Hist. Assoc. = Studies and Records of the Norwegian-American Historical Association
 Tr. Assoc. Am. Phys. = Transactions of the Association of American Physicians
 Tr. Chicago Path. Soc. = Transactions of the Chicago Pathological Society
 Tr. Cong. Am. Phys. Surg. = Transactions of the Congress of American Physicians and Surgeons
 Tr. Minn. Path. Soc. = Transactions of the Minnesota Pathological Society
 Tr. Sec. Path. Physiol. A.M.A. = Transactions, Section of Pathology and Physiology of the American Medical Association
 Univ. Chicago Mag. = University of Chicago Magazine
 Virchow's Arch. f. path. Anat. = Virchow's Archiv für pathologische anatomie und physiologie und klinische medizin
 West. Clin. Rec. = Western Clinical Recorder
 West. M. Rep. = Western Medical Reporter
 West. M. Rev. = Western Medical Review

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Raymond A. Pelaez

RAYMOND ALEXANDER KELSER

1892-1952

BY RICHARD E. SHOPE

Raymond Alexander Kelser was born in Washington, D. C. on December 2, 1892, and died in Philadelphia on April 16, 1952. While scarce 135 miles separated the place of his birth from that of his death, much of his scientific career was lived in farflung places and the influence of his work and the reputation which he achieved as veterinarian, bacteriologist and immunologist were world-wide.

Ancestry and Boyhood

Raymond Kelser's ancestors on his father's side were of German-English origin, his great-grandparents "Kelser" having emigrated to Baltimore in the early 1800's. His mother's people were of English descent through several generations in Virginia. His father, Charles Kelser, because of family illness, the death of his father, and financial reverses, had to go to work as a young boy, apprenticing himself at various trades and becoming a skilled mechanic. Charles Kelser married Josie Mary Potter when both were quite young. Eight children were born to them, 7 sons and 1 daughter, and Raymond was their first-born. Although Raymond was born in Washington, D. C., part of his early childhood was spent in Baltimore where the family lived for a few years.

Raymond's schooling was entirely in Washington, where he attended various public elementary schools in the northeast section of the city. According to Miss Julia Mae Rawlings, who taught him in his 7th grade work, he was an excellent, serious, and very responsible young student. He was an ambitious child with an intense desire for a good education, and by the time he had finished the elementary grades he knew definitely that he wanted a profession, either law or medicine. His youthful consideration of law as a profession undoubtedly stemmed from the countless hours he spent in his boyhood years around the Capitol, attending sessions of Congress, and also attending sessions

of Court in the various courts in Washington. The knowledge he retained therefrom was apparent in his adult years.

There were in Washington, during Raymond's boyhood, three Academic High Schools, one Technical High School, and one Business High School. Raymond had hoped that, on finishing 8th grade, he might enter one of the Academic High Schools. However, at about this time the Kelser family finances, none too good at the best, took a turn for the worse, and Raymond, therefore, received no encouragement at home regarding the higher education he so keenly desired. Instead, his father contended that a good business education in the Business High School, then a job, and then progress in the business world, was the course that Raymond should follow. Young as Raymond was, he understood that his father's decision was not from lack of desire for a higher education for his first born, but to a proud and independent spirit which prevented him from seeking financial assistance from those in his family who could have granted it. Although very much disappointed, Raymond followed his father's advice, and started his business course. To help finance this schooling, he acquired two paper routes, one an early morning one, and the other an evening one, and, in addition, did odd jobs in his spare time to earn extra money.

Towards the end of his "business course" Raymond decided to try to take advantage of the opportunity that then existed in Washington for taking collegiate courses in evening classes. He had learned that many Government employees were obtaining college degrees by attending these evening classes and that degrees in almost anything, including medicine, could be obtained in that way. He felt that if he could get a "Government job" which permitted him finishing his work by 4:30 P.M., he could not only finance, but would also have the time for, this evening college training.

With this plan in mind he went to the Civil Service Commission to try to obtain an appropriate "Government job". However, getting a "Government job" in those days presented numerous difficulties, especially to a resident of the District of Columbia. At that time no resident of the District of Columbia was eligible for a permanent appointment as a "clerk", the sort

of job Raymond had hoped to obtain. This apparent discrimination against D. C. residents seems to have resulted from the fact that on the State quota system then in effect the District had, at the time Raymond applied, far surpassed its allotment. Temporary appointments through Civil Service examinations for non-professional positions were few and far between (undoubtedly Uncle Sam was attempting to balance his budget even in those far-off days) and could be made only for a maximum of six months in any one Department of the Government and with a total of only eleven months in the Government service in any one year. The income resulting from such indefinite employment did not warrant assurance of the financing of a college education. As a consequence, in order to get an appointment as a clerk, Raymond would have had to go to some State for a year to establish "residence", take an examination, and then get his appointment from that State. Such a course of action was impracticable and so some alternative plan of procedure had to be worked out.

The alternative plan was simple but less remunerative. However, as will become evident, that alternate plan proved to be the deciding factor in molding the remainder of Raymond's life and his whole professional career and thus, while its prospects for immediate financial gain were poor, its value from the destiny standpoint was very great. The alternative plan involved the taking of a Civil Service examination for "messenger" instead of "clerk". A D. C. resident was at the time eligible to become a "messenger" even though barred by virtue of his residence from becoming a "clerk". The starting salary of a messenger was \$30 per month and by gradual stepwise increases could eventually reach a top of \$50. So at age 17 he took and passed the examination for "messenger".

At this point "Fate" or "Destiny" seems to have offered a guiding hand for Raymond's appointment as "messenger" was in the Bureau of Animal Industry of the United States Department of Agriculture. Fortunately, after working for a very short period of time as a messenger his ability was recognized by the late Dr. John R. Mohler, who was at that time Chief of the Pathological Division of the Bureau of Animal Industry.

Dr. Mohler set young Raymond to doing secretarial work in his division and eventually to working as a laboratory assistant. Raymond finished his preparatory schooling after office hours in various schools which offered evening courses.

Dr. Mohler took a very personal interest in Raymond and tried in many ways to have him appointed to other Government payrolls in order to obtain for him a salary that more nearly represented that which his work warranted. However, his efforts were unsuccessful because Raymond was a District of Columbia appointee and Civil Service could do nothing about it on a permanent basis. Raymond became Dr. Mohler's secretarial assistant and an assistant in the Pathological Laboratories of the Bureau. He was happy and interested in his work despite the small salary he drew during those years. It was natural that he became interested in the field of veterinary medicine and that he gave up the idea of studying law or medicine.

He enrolled in The School of Veterinary Medicine of George Washington University and completed the work required for his doctorate in veterinary medicine by attending evening classes there after he had completed his day's work in the Bureau of Animal Industry. Undoubtedly Dr. Mohler was Raymond's inspiration during the time that he was struggling to obtain his professional education. Equally certain it is, however, that Raymond was endowed with a tremendous will to succeed and achieve on his own in order to fight through to the completion of his higher education against odds that would have stopped a slightly less determined and ambitious boy. He graduated and received the D.V.M., to which he was to add such lustre, in 1914. Certainly had Horatio Alger himself planned Raymond's career along the usual lines used in his tales, he could not have outlined a more dramatic beginning nor one initiated in a more "self made man" manner.

Professional Career

After earning his doctorate in veterinary medicine in evening classes at George Washington University, young Dr. Kelser in 1914 did two things of importance. One of these was to marry Eveline Harriet Davison of Brookings, South Dakota, and the

other was to take his first professional position. His marriage, which occurred at the home of the bride's parents in Prince Georges County, Maryland, on September 5, 1914, was an extremely happy one, and lasted throughout the remaining 38 years of his life. His first professional appointment, on the other hand, that of bacteriologist at the H. K. Mulford Company, Glenolden, Pennsylvania, which he accepted immediately upon graduation, satisfied him less than a year and appears to have demonstrated to him that he was not cast for a role as a commercial scientist. Late in 1914 through Civil Service examination in his profession, he returned to Government service in the Bureau of Animal Industry, United States Department of Agriculture, and was assigned to field work in the eradication of foot-and-mouth disease, which had reached epidemic proportions in the United States. In the spring of 1915, he was assigned to the Pathological Division in Washington.

Back in the laboratory where he had worked as a "messenger" and secretarial assistant during his night school days, young Kelser again came under the inspiring influence of Dr. Mohler. Also he associated professionally on his return to the Pathological Division with other scientists and his natural bent for investigative work was stimulated by association with men like Eichhorn, Schoening, Traum, Hall and others in the division. He "took" to laboratory work very naturally and during the period 1915-1918 that he served in the Bureau of Animal Industry he demonstrated clearly that he possessed genuine talent for original investigative work. With Eichhorn and Berg he fractionated anthrax serum and found its therapeutic activity to reside in the globulin fraction. He worked with Berg on tetanus antitoxin and by studying its inactivation with acids, alkalis and proteolytic enzymes came to the conclusion that, while the antitoxic activity was closely associated with the serum proteins there was good evidence for its not being protein in character. Working with Eichhorn he developed a spore vaccine for anthrax that was a definite improvement over the older Pasteur vaccine previously used. In his first single-handed and entirely independent investigation he carried out studies of methods of immunization against blackleg and made interesting and im-

portant observations on the efficacy and mode of action of natural aggressins and toxic culture filtrates in inducing immunity. In this work he observed that the mechanisms by which the natural aggressin and the toxic culture filtrate induced immunity to blackleg were probably different. He did a piece of work on equine infectious abortion (bacterial) which advanced the then current knowledge of the etiology, diagnosis and immunology of that condition.

In March 1918, with the United States involved in World War I, Kelser gave up his work in the Bureau of Animal Industry and entered the Veterinary Corps of the United States Army as a Lieutenant. His Army career extended through 28 years until his retirement as Brigadier General and Chief of the Veterinary Corps in January 1946. Dr. Kelser's 3 years of work in the Bureau of Animal Industry had fully demonstrated his ability to do investigative work of an imaginative and original character, and from this beginning one might have predicted at least a part of the course that his Army career would follow if the Army gave him the opportunity to follow his natural bent and inclination. As it turned out, the Army appears early to have recognized Kelser's talents for research and to have given him opportunities to do investigative work; opportunities which he eagerly seized and made the most of.

His first military assignment was in the Army Veterinary Laboratory at the University of Pennsylvania for a few months training in Army laboratory procedure. His second assignment was that of Chief of the Veterinary Laboratory at the Letterman General Hospital in San Francisco. After about a year there he was returned to the University of Pennsylvania as Commanding Officer of the Army Veterinary Laboratory. In none of these assignments did he remain long enough to undertake original investigative work.

Kelser resigned his commission in the Army in 1920 and returned to work in the Bureau of Animal Industry. He remained there for only a few months. Late in 1920 he went back to military service, this time in the Regular Army, and was assigned to duty as Post Veterinarian at Camp Jackson, South Carolina. It was not until 1921, when he began a 4-year tour

of duty as Chief of the Veterinary Laboratory Division at the Army Medical School in Washington that he again got his research under way.

At the Army Medical School, Kelser showed his first interest in the filtrable viruses, a field in which he was later to make his most significant contributions. He worked for a while with equine infectious anemia and wrote a general review paper in which he speculated, from the results of his own work, that the causative virus might be protozoan in character. He studied equine influenza, compiling a general treatise on the method of handling the disease. In this he speculated at considerable length concerning the possibility that a virus was of etiological importance. Later he conducted experimental work with rabies in which he presented evidence that the Negri body, which he considered to be protozoan-like, actually represented a visible stage in the life history of the rabies virus.

In addition to his work in the field of viruses, Kelser, while at the Army Medical School, made a study of *Clostridium botulinum* and its toxin in culture and canned food products. In connection with this study, he perfected a complement fixation test which was of considerable practical value for detecting botulinus toxin in suspected canned foodstuffs.

During his 4-year tour of duty at the Army Medical School, instead of spending his "off duty" hours leisurely, Kelser registered as a graduate student in the Graduate School of American University in Washington, D. C., securing therefrom his A.M. and Ph.D. degrees.

From 1925 to 1928, Dr. Kelser served as a member of the United States Army Medical Department Research Board in the Philippine Islands and it was while working with this board that he made one of his most significant findings. Cattle plague had long been a serious scourge in the Philippines, affecting as it did both cattle and carabao, and markedly hampering agricultural pursuits in the islands. Kelser studied the disease as it prevailed and undertook the development of a vaccine to combat it. Using blood and tissues of animals ill of the disease he sought a chemical agent which would be capable of inactivating the virus without destroying its immunizing

properties. After many trials he found that chloroform possessed the chemical activity he desired, and that the addition of it to the virus in tissue suspension yielded a preparation that was safe to administer to cattle and carabao and that possessed good immunizing powers. This was the first "killed virus" vaccine that utilized chloroform as the inactivating chemical.

Kelser's vaccine, as finally perfected, was made using a suspension of spleen, liver and lymph nodes from cattle ill of cattle plague in which the virus was inactivated by 0.75% chloroform. It was used extensively and with marked success and is generally credited with being the main factor responsible for the eventual eradication of cattle plague in the Philippines.

Aside from the practical importance of the vaccine, certain theoretical considerations of fundamental interest emerged from Kelser's work with cattle plague. He observed that though the blood of sick cattle was rich in virus, it was devoid of immunizing capacity when treated with chloroform. This led him to the interesting hypothesis that the immunizing principle was not the chloroform-inactivated cattle plague virus itself but rather either some tissue product of reaction between virus and cells or some particular stage of the virus occurring only in tissue cells. While his work did not settle the matter concerning the nature of the immunizing substance in the vaccine, it did rather clearly demonstrate that it was not merely "killed virus". The question is still one of considerable theoretical interest in the virus field.

Another study of interest and importance carried out by Kelser in the Philippines was one dealing with the mechanism of transmission of surra among horses. In a series of ingenious experiments he proved that the fly *Tabanus striatus* was the vector responsible for transmitting *Trypanosoma evansi* to the horse in inducing surra. He demonstrated that transmission of the trypanosome by the tabanid fly was purely mechanical and that the horse was an accidental host. The true animal hosts of *T. evansi* appeared to be cattle and carabao and Kelser found that approximately 50% of these were trypanosome carriers. He pointed out the interesting fact that if *T. evansi* had been carried by a permanently infected insect that fed on horses,

instead of being transferred mechanically by the tabanid, horses would have been wiped out in the Philippines long ago.

The Army brought Kelser back from the Philippines in 1928 and placed him once again in charge of the Veterinary Laboratory Division at the Army Medical School. He remained in this position for 5 years and found the time and opportunity, in spite of heavy routine and teaching responsibilities, to do two pieces of research; one good, and the other outstanding. Following up the success he had achieved in developing a cattle plague vaccine using chloroform as a virus-inactivating agent he applied similar methods in attempting to perfect a better rabies vaccine than was then available. He found, as he had in the case of cattle plague, that chloroform added to tissue suspensions containing rabies virus inactivated the virus and rendered the suspension safe for administration to susceptible animals. Furthermore, infected tissue suspensions containing the chloroform-inactivated rabies virus proved effective in immunizing against the disease. The new vaccine possessed certain advantages over the then currently used "killed virus" rabies vaccines in the protection of dogs and other animals. A fact of some theoretical interest observed by Kelser was that tissue components, in addition to virus *per se*, were essential to the production of a satisfactory rabies vaccine. Kelser reasoned from this, as he had in the case of his cattle plague vaccine, that the immunizing substance must be more than merely dead virus and might be either a particular developmental stage of the virus or a cellular principle resulting from reaction between virus and tissue cells. Again, however, his work left undecided and unsettled the question of the nature of the immunizing substance.

The second piece of research carried out by Kelser on his second tour of duty at the Army Medical School, and the one for which he is probably most widely known, dealt with the mode of transmission of the virus of equine encephalomyelitis. The epidemiology of equine encephalomyelitis was at the time a complete mystery and there were not even any very good guesses as to how the causative virus spread from horse to horse to cause the highly fatal and widespread epizootics that prevailed in the

late summer and early autumn in many parts of our country. The disease, being one with predominantly neurological signs and in which virus was present in high concentration, during the time animals were clinically ill, only in the central nervous system did not on the surface suggest an insect vector. However, Kelser was aware of the fact that a stage of viremia, frequently almost asymptomatic, preceded the fatal neurological stage of the disease and he reasoned that it might be during this period that the virus was transmissible and that when it was present in the blood stream, a blood sucking insect conceivably might be important as an intermediate host. With this idea in mind he tested the possibility that mosquitoes might serve to transmit the virus from animal to animal. Working first with experimentally infected guinea pigs he demonstrated transmission from infected to normal animals by the mosquito *Aedes aegypti*. Later he proved transmission to horses by the same mosquito. Kelser's important initial observation has been repeatedly confirmed and the species of mosquitoes, other than *A. aegypti* that can and do serve as intermediate hosts for the equine encephalomyelitis virus under both experimental and natural conditions have been extended.

Kelser's discovery of the role played by a mosquito as intermediate host for the equine encephalomyelitis virus constituted the first demonstration of transmission of a neurotropic virus by an insect. It led to the discovery by other workers that a similar mechanism of transmission prevailed in other neurotropic virus infections of man and animals and has done much to influence medical thought on the epidemiology of this class of disease. It was a very important observation.

From 1933 to 1935 Kelser was at Harvard as a research fellow in Zinsser's department. He gained much of intellectual and scientific value from this contact with Zinsser and others at Harvard and often spoke of those two years in happy terms. He had an opportunity for extensive reading and for perfecting himself in certain laboratory techniques that might later be useful to him. He published only one paper while at Harvard, a piece of work done with Lester King, dealing with a paralysis syndrome produced in rabbits and guinea pigs by extracts of

normal primate bone marrow. In this work it was proven that the paralysis producing principle present in normal bone marrow, spleen and leucocytes of man and monkey was not viral in nature, nor did it enhance the effect of low grade viruses. Rather it was considered that the principle was chemical or enzymatic in character and was probably identical with Jochmann's proteolytic ferment.

Upon completion of his Harvard research fellowship, Kelser returned to full Army duty and was assigned for a three year tour in Panama, doing investigative work with other members of the Army Medical Research Board located in the Gorgas Hospital area in Ancon, Canal Zone. In addition, he cooperated in investigative work with the Gorgas Memorial Laboratory located in Panama City, Republic of Panama. His work in Panama dealt with Chagas disease, equine encephalomyelitis, and degenerative arthritis. He perfected a medium in which heavy cultures of *Trypanosoma cruzi*, the causative agent of Chagas disease, could be grown, and utilizing such cultures in the preparation of antigen, developed a satisfactory complement fixation test. This test made possible an accurate survey of the Canal Zone for Chagas disease. Johnson and he, using this test, found a much higher incidence of the disease in Panama than had been formerly thought.

While in Panama, Kelser had an opportunity to study equine encephalomyelitis further under natural conditions. Cases of the disease occurred in horses in the Canal Zone and the causative virus was the so-called Western type. Kelser studied the epidemiology of the natural disease and did experimental transmission experiments in guinea pigs. He found that the mosquito, *Aedes taeniorhynchus*, was capable of transmitting the western type of equine encephalomyelitis virus. Furthermore, he demonstrated that the mosquito did not transmit the virus mechanically but that the virus must undergo a developmental period within the mosquito before it was capable of transmission. He did not determine the maximal period during which transmission could be effected, but did learn that the infected mosquito could infect animals that it fed upon as long as it could

be kept alive under laboratory conditions which in one case was 32 days.

With Callender, Kelser did some work of a pathological observational character in Panama on degenerative arthritis in man and horses. The differentiation of degenerative arthritis of equines from the nutritional deficiency disease of "big head" in mules was an example of the forming of a well conceived plan involving the nutritional and chemical fields, including not only the metabolism of the animals, but the nutritive value and chemistry of their diet.

Kelser's work in Panama turned out to be his last opportunity to conduct research. After 3 years there he was brought back to Washington and appointed Chief of the Veterinary Division in the Office of the Surgeon General of the War Department. He had, in the relatively short span of 20 years of Army duty, reached the highest position to which an Army veterinarian could attain. He served as Chief of the Veterinary Division from 1938 to 1946, which covered the active, important and exciting period of World War II.

Administrative Military Career

While Kelser had, throughout his earlier military career, certain administrative responsibilities inherent to the Army, his main responsibilities and contributions had been as a scientist doing research in the field of animal pathology. Now, with his appointment as Chief of the Veterinary Division in the Office of the Surgeon General, he was taken completely away from his beloved laboratory work and the opportunity to do research, and placed in charge of the entire Veterinary Corps of the Army. In 1938, with war clouds already gathering on the horizon, this was a very major administrative and organizational job as the Veterinary Corps, like all other branches of our armed services was rapidly expanding and increasing in complexity to meet the war emergency that even at that time seemed eminent. Kelser worked extremely hard. Being naturally an early riser, he spent inordinately long days in his office. Friends of his used to josh him about arriving at his

office early in order to have it open for the cleaning people and janitors when they should arrive.

During the time of Kelser's service as Chief of the Veterinary Division, the Veterinary Corps underwent an orderly expansion from 126 officers in 1938 to over 2200 at the height of its war-time activities. In conjunction with this marked increase in personnel there was also great expansion in Army veterinary facilities which only one of outstanding administrative ability such as Kelser possessed could have carried through successfully. It was he who in the end was responsible for the orderly running of the enormous military meat, food and dairy products inspection service that the Veterinary Corps conducted, both in this country and in foreign lands during the war, and it was his administrative competence that added much to the effectiveness of the service. It was necessary that the activities of the veterinary service be coordinated with other agencies of the Government such as the Department of Agriculture, the War Production Board, the Navy, the War Food Administration, the Pure Food and Drug Administration, and the Public Health Service, as well as with the civilian veterinary profession. This was done in a superior manner and with excellent results under Kelser's administrative guidance and aided greatly by his tact, diplomacy and ability to get along well with his fellow men. Kelser had a very large personal acquaintance with many of the people in key Government positions during the war and this facilitated the accomplishment of those of his tasks requiring close cooperation between governmental departments. He had the respect and friendship of all who knew him.

Kelser was a complete patriot and service to his Government was his creed. Many demands were made on his knowledge and talents by Government services outside the Army and each time he was called upon he responded wholeheartedly. He aided the Bureau of Animal Industry frequently and in many ways. Even during the busy war years, when his position as Chief of the Army Veterinary Corps kept him so fully occupied, he accepted appointment as Chairman of the Joint United States-Canadian Commission dealing with biological

defense matters and carried out this assignment with great effectiveness and distinction.

It was during the time that Kelser served as Chief of the Veterinary Corps that the Army advanced the rank of its chief from Colonel to Brigadier General. Kelser was pleased and proud that "the star" had come to the Veterinary Corps, not because the star was on his shoulder, but because the Army had given this recognition to the Veterinary Corps and the veterinary profession.

Return to Civilian Life

Upon his retirement from the Army in 1946, Dr. Kelser had a number of professional positions in civilian life offered to him. He decided to accept an appointment at the University of Pennsylvania as Professor of Bacteriology and Dean of the School of Veterinary Medicine. During his six years at Pennsylvania he made outstanding accomplishments in building up the physical plant, faculty, and general program of the Veterinary School. By his example and through his encouragement he stimulated an active and productive research program and a far-seeing program in teaching. He aided in initiating a retirement program for faculty members. By applying his dynamic energy and his remarkable capacity to draw enthusiasm and support from others, he was especially effective in obtaining much needed financial support for the school. Kelser was known in his profession as one of the most widely experienced and best informed veterinarians of his time. His grasp and vision of veterinary science and education were extremely broad and he promoted the advancement of his profession whenever opportunity offered.

Dean Kelser was respected and liked by his faculty and was popular with the student body of the veterinary school. He was never too busy to participate in student activities when he was asked. It is of interest to point out in this connection that on the day of his death he had attended a luncheon at noon with his senior students.

During the time that Kelser was Dean of the School of Veterinary Medicine at Pennsylvania, he also had a host of

other activities. Among other things he served as Consultant to the Secretary of Defense in Biological Warfare problems, and to the Chief of the Bureau of Animal Industry on Foot-and-Mouth disease research. He was Chairman of the Board of Scientific Advisers of the Grayson Foundation. He gave unselfishly of his time and energy to these outside activities despite his already full schedule of university activities.

Personality

Kelser was a well built, robust man, with an apparently boundless energy for work. He had a delightful sense of humor and a remarkable ability to tell stories illustrating points he wished to make in discussions. He was forceful and possessed of a natural aptitude for leadership. He was persuasive, firm and determined in the face of opposition if he felt that his views were the correct ones. He had a sincere respect for achievement in others and recognized just authority unquestioningly. During his career, he was frequently placed in the position of having to make decisions that were not always popular with all concerned and at times that even appeared arbitrary to some, but he held no apparent rancor for those who opposed or disagreed with him. His ability to pass easily and rapidly from a serious to a jocular mood and to see the humorous sides of tense situations was a characteristic that proved valuable on many occasions. He threw himself wholeheartedly into anything in which he participated and was apparently incapable of playing a passive role. On committees and in discussion groups, Kelser was always an active and intelligent participator and there was nothing of the "rubber stamp" in his make-up. He had an almost uncanny ability to analyse motives and to himself think clearly through situations in which divergent opinions prevailed. He could marshal his own thoughts in an orderly manner and express them clearly and persuasively.

Kelser was socially alert and completely human in his zest and joy for life. He liked people and was an entertaining conversationalist. He made friends easily. He enjoyed parties and social gatherings with friends, though he had little time for such things. He was musically talented and played several

instruments well. He also enjoyed watching the horse races. He was sympathetic and understanding towards the problems of others and willingly gave of his help and advice if it was asked and he considered it would be of value. He possessed not a trace of snobbery.

In his young manhood he took an active interest in Free Masonry, becoming a thirty-second degree Mason, and a Shriner. As a young Army officer, he was active in the Sojourners, Heroes of '76, and the Military Order of the Carabao. He was a member of the Army and Navy Club in Washington, D. C., and a founder member of the Army-Navy Country Club in Arlington, Virginia. The Lenape Club of the University of Pennsylvania claimed him as one of its members.

A former military colleague of Kelser's has written as follows: ". . . Wherever he served he left a host of admirers high in his praise as a scientist, soldier, and gentleman, and, I assure you, he was a difficult man to follow. I should know, having relieved him on four separate occasions. Considering the pace maintained by Ray, I guess the Good Lord deemed his earthly attainments sufficient and called him to loftier chores and, who knows, perhaps his spirit may be busily engaged in whispering encouragement and suggestions to frustrated scientists who, also, are endeavoring to make this a better place of abode."

Kelser was deeply devoted to his family and was with them as much as his busy life permitted. He never took a vacation trip without them and during his earlier military assignments his wife and daughter accompanied him to his foreign posts. Mrs. Kelser was his complete confidante and much of the personal material that the writer has used in this memoir has been obtained from her. From the wealth of this personal material it is evident that Kelser shared his full life completely with his wife. She was his helpmate and frequently typed, proofread, and criticized his manuscripts, though she never worked with him in his laboratory. The Kelsers were devoted to one another and enjoyed a real husband and wife comradeship.

Kelser had but one child, a daughter, Evelyn Rae, now Mrs. John A. Allgair (wife of Lt. Col. John A. Allgair, C. E. U. S.

Army) whom he affectionately called "Boots." It was readily apparent to all who knew him that she was the "apple of his eye" and he frequently spoke of her to his close friends. He also often told amusing anecdotes of his two grandchildren, and was very much wrapped up in their lives. Mrs. Allgair has given the writer some of her impressions of her father which shed considerable light on his personality. Some brief quotations from her letter furnish an insight into Kelser's personality that many who knew him only casually may have missed.

She wrote, ". . . No matter how busy he was or how over-worked or tired, he never objected to my bringing home one or a whole gang of my friends and if I wanted his assistance, was always willing to help with the plans for my entertaining. He wasn't the kind who could relax his dignity and romp with us kids, but he was always glad to foot the bills, do the chauffeuring, run the movie projector, or mix the punch.

"As you probably know, dad was a complete 'softie' when it came to his grandchildren. Though he was a strict disciplinarian with me, my two could wrap him around their fingers. I seldom remember him even getting angry with either Bucky or Cherrie, no matter how aggravating they became. During the 18 months I lived at home during the war, hardly a night went by that he didn't spend an hour or so making up lengthy cowboy and Indian tales which he told to the kids. It was always a new and different story, and, like everything else that dad did, was well done. I used to often wonder how, after a full day of dealing with the many wartime problems which confronted him, he still had the mental energy to create the children's stories. Dad was always the one who took on the nursing duties when the children were sick, no matter how tired he was.

"For a scientist, I think dad had an unusual appreciation of art and music, and the beauties of nature. He probably could have been quite a musician if he had had the time for it. I remember the pleasure he found in the flowers, particularly the roses, in our various gardens. He would often cut just one or two of the most perfect ones in bloom and comment a number of times upon their beauty. He was artistic in his gardening and

in the decoration of his home, and it was usually dad who did most of the decorating of our Christmas trees as he was the one who could do it best."

Raymond Kelser was active right up to the time of his death which occurred suddenly on April 16, 1952, as a result of cerebral hemorrhage. He will be missed by his host of friends, both in and outside his profession, and in Government and military circles, who admired, respected and loved him. While no one is absolutely indispensable, Raymond Kelser, because of his unique and wide and varied talents and expert knowledge in his particular and specialized fields of interest, comes about as close to being irreplaceable as anyone could be.

Honors and Memberships in Scientific Societies:

National Academy of Sciences

American Association for the Advancement of Science

American Veterinary Medical Association (Vice-President
1929-31)

American Public Health Association

American Academy of Tropical Diseases

American Society of Tropical Medicine

American Association of Pathologists and Bacteriologists

Association of Experimental Pathologists

Association of Military Surgeons

Washington Academy of Sciences

New York Academy of Sciences

Sigma Xi

Phi Zeta

Distinguished Service Medal

Gorgas Medal

12th International Veterinary Congress Prize

George Washington University Alumni Achievement Award

Diploma, Honorary Associate of the Royal College of Veterinary
Surgeons, London

Sources and Acknowledgments

The writer is deeply indebted to Mrs. Raymond A. Kelser for her cordial and friendly help in obtaining and furnishing

much of the information contained in this account. Dr. Kelser's daughter, Mrs. John A. Allgair, was also very helpful in supplying personal information about him. Miss Edna W. Tuteur, Dr. Kelser's secretary at Pennsylvania, aided greatly in getting together his bibliographical material. Personal letters from many of Dr. Kelser's friends and former associates, giving reminiscences on periods of his life with which the writer was not personally familiar, were of extreme interest and very helpful in preparing this account. The writer feels particularly indebted for such letters to Brigadier General George R. Callender, Dr. Adolph Eichhorn, Colonel James A. B. Gibson, Colonel Albert G. Kinberger, Mrs. John W. Potter, and Colonel Francois H. K. Reynolds.

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

- Am. J. Path. = American Journal of Pathology
 Am. J. Pub. Health = American Journal of Public Health
 Am. J. Trop. Med. = American Journal of Tropical Medicine
 Ann. N. Y. Acad. Sci. = Annals, New York Academy of Sciences
 Cornell Vet. = Cornell Veterinarian
 J. Agric. Res. = Journal of Agricultural Research
 J. Am. Vet. Med. Assn. = Journal of the American Veterinary Medical Association
 J. Bact. = Journal of Bacteriology
 Mil. Surg. = Military Surgeon
 Philippine J. Sci. = Philippine Journal of Science
 Proc. 12th Internat. Vet. Congr., U.S. Govt. Printing Office = Proceedings of the 12th International Veterinary Congress, United States Government Printing Office
 Tr. Seventh Congr. Far Eastern Assn. Trop. Med. = Transactions of the Seventh Congress of the Far Eastern Association of Tropical Medicine
 Vet. Alumni Quart. Ohio State Univ. = Veterinary Alumni Quarterly, Ohio State University
 Vet. Bull. U.S. Army = Veterinary Bulletin, United States Army
 Vet. Exten. Quart. Univ. Pa. = Veterinary Extension Quarterly, University of Pennsylvania
 Vet. Med. = Veterinary Medicine

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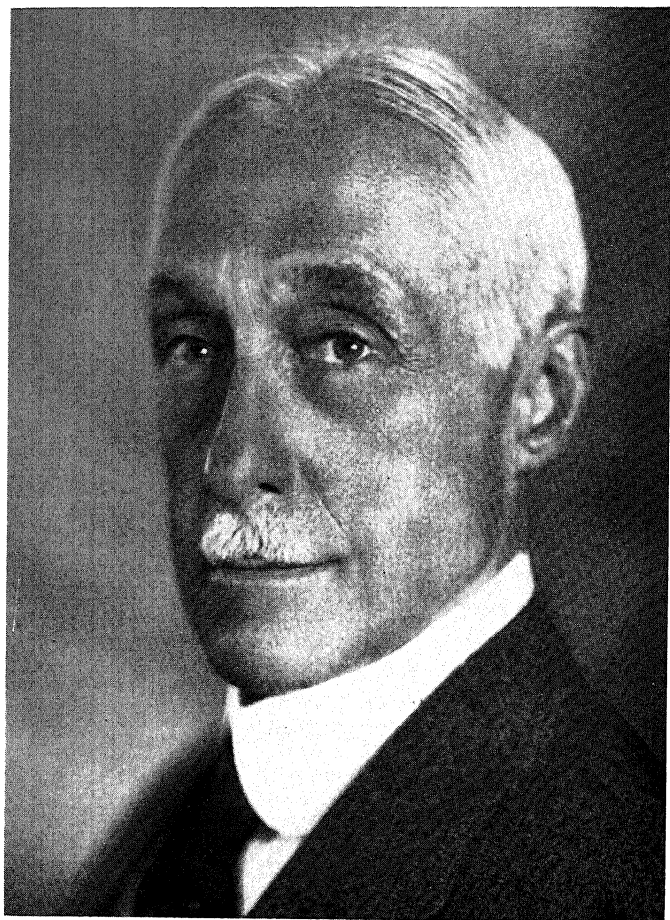
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Chas. A. Sperry.

ELMER AMBROSE SPERRY

1860-1930

BY J. C. HUNSAKER

Elmer Ambrose Sperry, inventor and pioneer in the field of applied electricity, was born to Stephen Decatur Sperry and his wife Mary Burst in Cortland, New York, October 12, 1860, and died in Brooklyn, June 16, 1930.¹ Richard Sperry, the first of the family to arrive in America, settled in 1634 just north of New Haven. In a cave on his farm he hid the Regicide Judges who condemned Charles I to death in the time of Cromwell. A ridge on the Sperry farm, recently tunneled for the Merritt Parkway, became the site of West Rock Park.

Elmer Sperry's mother died at the birth of her only child and he was reared by his widowed aunt, Helen Sperry Willett. His father worked for the Cortland Wagon Company, whose wagons were driven up and down the seven valleys radiating from Cortland and were occasionally taken by Stephen Sperry as far as New York or Chicago.

Young Sperry's inventive bent showed itself early. As a boy he built nutmeg graters, waterwheels, windmills and a tricycle that he could pedal on the railroad tracks, just ahead of the local freight, in exciting races to safety. He was fortunate to live in Cortland where he could attend classes at the State Normal School, one of the first schools in the United States to offer instruction in electricity. Sperry was a good student and electricity captured his interest. He began by constructing batteries in glass jars, insulating the wire as well as winding coils. He was allowed to install a system of electric bells in the school.

While still attending Normal School, Sperry visited Cornell University, a short buggy ride away. After graduation, he enrolled as a special day student at Cornell for the year 1879-80. The attraction was the laboratory in which Professors Anthony, Ryan and Sweet were building an electric dynamo. Sperry, a skilled mechanic from shop experience acquired during vacations

¹ Dictionary of American Biography, Scribners, New York.

at the Cortland Wagon Company, was allowed to help. When the dynamo was sent to the Philadelphia Centennial Exposition in 1875, he went along. Here he spent many fascinating hours in the Machinery Building where the complicated Jacquard loom, the Corliss engine with its great walking beam and fly-wheel, and another dynamo like the one from Cornell, but made by a Frenchman named Gramme, were all operating. Sperry remembered that trip for the rest of his life.

Copies of the *Patent Gazette* were available in the reading room of the Cortland Y.M.C.A., and it is reported that Sperry waited eagerly for each new issue to arrive. He believed implicitly in all mechanism illustrated in the *Gazette*, studying carefully each of the claims. Years later, some of our most able patent attorneys remarked that Sperry was the best claim writer of them all. Thus he acquired a soft spot in his heart for the Y.M.C.A. He contributed time and money toward its support during his lifetime and made it a generous gift in his will.

While Sperry was a student at Cornell, he began to work on ideas to improve generators and arc lights. This probably marked the beginning of his long inventive career. For nearly fifty years thereafter he was an unusually productive worker. He was granted more than four hundred patents, the most important dealing with dynamos, arc lights, electric locomotives, mining machines, trolley cars, storage batteries, electrochemistry, applications of the gyroscope, gun-fire control apparatus, and finally a method of detecting defective rails in track.

Dynamos, Arc Lights and Power Plants

Sperry built a generator and arc light at the Cortland Wagon Company and illuminated the Christmas Festival at Cortland in 1879. On the advice of his father, who considered the city of Chicago the most progressive in the country, he took his arc light and generator there in 1880. He presented a letter of introduction to a deacon of the Baptist Church and rented factory space.

"On my twentieth birthday I opened my shop (The Sperry Electric Illuminating and Power Company) on West Quincy

Street," he wrote. "My first contact with electric lighting in Chicago came that winter in 1880-81 when I put in an installation of twenty lights on the Clark Street front of the County Building. The lights were stretched on long poles sticking out from the building all along the facade. The dynamo was running in the basement

"The next year I started one of the first central stations in Chicago, having my plant in the basement of the Commercial National Bank Building and extending my wires to the Chicago Tribune, the Inter-Ocean, Carson Pirie Scott, Kranze Candy Company, and a large number of small stores, restaurants, etc. in that vicinity. Later on I placed on the top of the Board of Trade Tower, 303 feet from the ground, a ring of lights aggregating 40,000 candle-power which were the highest and most powerful of the period. . . .

"Although most of the places lighted from this central station were lighted by arc lights, I remember we fitted up the composing room of the Chicago Tribune Building with a multiple series of incandescent lights from a large arc light generator."

Sperry's lighting business was very successful. He furnished light to Omaha and Council Bluffs. He had plants in Kansas City and St. Louis, and in several towns in Illinois, Indiana, and Ohio. He was awarded a contract for lighting the Interstate Exposition held in Chicago each year and won medals for excellence of apparatus. He also illuminated a large part of the World's Columbian Exposition of 1892-93. In Chicago B. E. Sunny bought out the Arc Light and Power Company which was using Sperry equipment and Sperry's downtown power station and, after acquiring other stations, put them together into an organization which later was expanded into the present Commonwealth Edison Company of Chicago. Sperry sold his arc light patents to General Edison Company of Schenectady, later combined with the Thompson-Houston Company as the General Electric Company.

High Intensity Arc Light

Many years later, in 1914, the Navy needed a more powerful searchlight because of the increased range of naval turret guns.

Sperry joyfully tackled the job, which to him was like renewing acquaintance with an old friend. He sent a young research engineer, Preston Bassett, to the National Carbon Company where he was well received, for Sperry had been a big user of carbons. Many experimental carbons were made following Sperry's suggestions and tested under Bassett's supervision. A new type of arc was eventually produced which greatly increased the effectiveness of existing searchlights.

In the ordinary carbon arc, the light comes from the end of the positive carbon. The carbon surface, when heated to its volatilizing point, has a brightness of 160 candlepower per square millimeter, the maximum that can be obtained from the incandescence of solids. Gas, however, is capable of intrinsic brilliance in the neighborhood of 1400 candlepower per square millimeter. Sperry made his positive carbon with a core of cerium fluoride which consumed faster than the outside shell, forming a crater in which gas emanating from the core was heated to incandescence. This gave a brightness five times greater than the best previous continuous source of light, and made practicable a searchlight of a billion candlepower.

The new high intensity arc was soon recognized as an outstanding accomplishment. For years Sperry did all the military searchlight business, and his searchlight, when used with anti-aircraft guns, helped beat off night air raids over London and Paris during World War I. His military searchlight later found commercial application for airway beacons and airport floodlights.

As an unforeseen application, the Sperry arc light made a valuable contribution to the motion picture art. Its high actinic value permitted indoor photography of motion pictures without sunlight. It was generally adopted by the studios, especially after the "talkies" made outdoor work too difficult.

In 1920, S. L. Rothafel brought to Sperry the problem of proper vision for customers in the far-distant galleries of his projected Roxy Theatre. The old-style light would not give enough illumination to the screen for so vast a space. Sperry's light solved the Roxy problem and made possible picture pro-

jection before large audiences. It is still in general use in outdoor movies.

Electric Mining Machines and Locomotives

After dynamos had become generally available for generating electricity, and transmission lines for conducting it, Sperry turned naturally to inventing and building machines to be operated by electric motors.

In the coal mines near Chicago cutting was done by pick-axe, and it took a strong mule to haul one small coal car out of the mine. While on his honeymoon in 1887, Sperry became acquainted with a mine operator and saw that electricity might revolutionize mining, but he was advised that copper wire would not hold up under corrosive mine water conditions.

Sperry found that a slight rise in the temperature of the copper wires would prevent condensation, and this he provided by maintaining a small current in the circuits. His first electric mining machine was designed to duplicate pick mining with the power of the stroke increased a hundredfold. A number of mines were equipped with these "punchers" with excellent results. Machines of this type were soon replaced by continuously operating chain cutters, designed by Sperry, which could cut much faster. Variations of this type of cutting machine are in general use today.

His machines increased coal production so much that Sperry rushed to completion an electric locomotive which could haul out 1,000 tons a day, replacing mine mules and their associated difficulties. To operate on the existing light tracks, the weight of the locomotive had to be distributed along the rails. Sperry conceived an eight-wheeled locomotive having two swiveling trucks flexibly mounted so that the wheels could follow irregularities in the track and at the same time maintain mechanical connection with a single electric motor.

Today in the mining display section of the Rosenwald Museum in Chicago is an exhibit: "Early Electric Locomotive from Northern Fuel Company's mine at Jacksonville, Ohio, where it was used continuously for eighteen years, designed by Elmer A. Sperry in 1887; weight, 8 tons; wheel diameter, 20"; motor, 60 horsepower."

The Sperry Electric Machinery Mining Company was incorporated in 1888 and in January 1890 received the first large order to be placed for electric mining machinery in the history of the industry. The order from Pickands-Mather and Company of Cleveland was for an entire plant with boilers, engines, three generators, switchboards, two locomotives, and sixteen chain-cutting machines. Then the "hard times" of the early 1890's brought the business to a standstill. Herbert E. Goodman, Sperry's brother-in-law who had been his general manager, raised new capital in Chicago and started the business again on Halstead Street under the name of the Goodman Manufacturing Company. Sperry put in more money too, with Frank S. Washburn who was made president. Sperry became vice-president and Goodman general manager. This company, now largely owned by the families of the three founders, is still doing business at the same address. Washburn later brought over an electrolytic process from Germany, and with Sperry advising as electrical engineer, set up a plant at Niagara Falls, making the beginning of the American Cyanamid Company.

Arthur D. Dana, who was Sperry's financial advisor and best man at his wedding, took a fuse wire producing machine Sperry had invented, and formed in 1889 the very successful Chicago Fuse Wire and Manufacturing Company. Dana also founded the Appleton Electric Company, with Sperry as president and A. I. Appleton, Sperry's former factory superintendent, as general manager, to make small motors and accessories. Sperry was an officer and a stockholder in these three Chicago companies. From Cleveland or from New York he assisted in the direction of their activities by correspondence. Later, needing money for his new inventions, he sold his Fuse Wire and Appleton stock to Dana and Appleton respectively.

Electric Trolley Cars

Because Sperry had built electric mining locomotives, he was approached by a group of men faced with the problem of operating electric railways in hilly territory. In the group were Tom L. Johnson, later Mayor of Cleveland, and Myron T. Herrick, later Governor of Ohio and Ambassador to France. Sperry

built for them a hill-climbing trolley car using the principle of his mine locomotive, i.e., driving all the wheels mechanically from a single powerful motor through a coupling permitting relative motion between the motor, mounted on the spring-supported body of the car, and gears on the axles. Another innovation was an electrical braking system which has since been used extensively. His general mechanical scheme is used for the same purpose today on the single-motor Pennsylvania Railroad electric locomotives. Professor H. J. Ryan, Dr. Louis Duncan, and Dr. D. C. Jackson officiated at a competitive hill-climbing test at the Chicago World's Fair, which Sperry won.

The Sperry Electric Railway Company was organized in 1890 to manufacture cars in Cleveland, and Sperry moved his family there to a house at 855 Case Avenue. Soon cars were operating in Youngstown, Pittsburgh, Waterbury, and Philadelphia, and Sperry set up an office in New York at 29 Broadway. Several hundred cars had been made when the newly formed General Electric Company bought the business and Sperry's patents in 1894. Sperry became a consulting engineer to General Electric for a time.

Electric Automobile and Storage Battery

Before disposing of the Sperry Electric Railway Company, Sperry designed an electric automobile² and had it built by the Cleveland Machine Screw Company. He took John D. Rockefeller, whom he met at the Baptist Church, for his first automobile ride. Two features of Sperry's electric automobile were far ahead of the time, four-wheel brakes and a non-reacting self-centering steering system.

The French owners of the Cleveland Machine Screw Company persuaded Sperry to take his automobile to Paris in 1896. There it proved so successful that manufacturing rights for France were purchased and the Cleveland Company received an order for 100 vehicles for shipment to France. American rights were taken over by the American Bicycle Company, and the car was marketed as the Waverly Electric.

² *Electrical World and Engineer*, July 22, 1899, p. 127.

The battery developed and patented for this car was the most important element because it became the forerunner of the portable lead storage batteries in use today. Sperry put his plates in a hard rubber container with an elastic plate support at the bottom. The plates had a porous pyroxylin envelope which held the active material in position regardless of rough usage. His automobile ran 100 miles on one charge of this battery at a time when 36 miles was considered good. The National Battery Company of Cleveland was formed about 1900 by R. L. Coleman, president of the American Bicycle Company, to manufacture the battery with Sperry as chief electrical engineer. The company was moved to Buffalo in 1901 and taken over by a railway car lighting company in which Walter Chrysler and John N. Willys were active. When these men switched from railroad equipment to automobile manufacture, the company was merged into Electric Auto-Lite.

Electrochemistry

Sperry's work on the automobile battery led him into electrochemistry, and in 1900 he equipped a research laboratory in Washington with Clinton P. Townsend as electrochemist in charge. Sperry supplied the cash and his knowledge of electrical engineering. During the laboratory's ten years of existence a number of useful processes were evolved, the most notable of which was the Townsend process for the manufacture of caustic soda from salt, accompanied by the production of hydrogen and chlorine. This process became the basis of the business of one of the largest American manufacturers of caustic soda and chlorine products, the Hooker Electrochemical Company of Niagara Falls.

In 1904 Sperry contracted with the American Can Company to develop a chlorine detinning process, and the following year moved his family to Brooklyn, where he lived for the rest of his life. A new detinning process was developed which also produced a product more valuable than tin. This product, anhydrous tetrachloride of tin, was sold to the silk industry to replace the bichloride of tin then used in processing silk. Sperry made arrangements for the American Can Company to operate

the detinning process at Carteret, New Jersey, on the basis of some thirty Sperry patents. Several plants were erected across the country under the name of Goldschmidt Detinning Company, now the Metals and Thermit Corporation, controlled by the American Can Company.

When the business tide was low after World War I, Sperry attempted another electrochemical process, this time in his Brooklyn laboratory. The problem was to make white lead electrolytically from impure pig lead or from waste products of copper refining. Many diaphragm materials were tried in the electrolytic cell.

Colburn Pinkham, the controller of the company, showed Sperry a new shirt he was wearing which was made from a material that his brother in the textile business was marketing for the first time. It was called mercerized cotton. Sperry cut a piece from Colburn's shirt tail and put it under the microscope; it was just what he was looking for. A successful process was developed to make from impure lead a chemically pure product of intense whiteness superior to that yielded by the old Dutch method then in use. The process was sold to the Anaconda Copper Company and a large plant was set up at South Chicago.

Gyro Stabilizer

While Sperry worked on his electric carriage in Cleveland in the 1890's, he became interested in popular science articles on the gyroscope and discussed with Professor Dayton C. Miller of the Case School of Applied Science the possibility of using a gyroscope to keep his vehicles from tipping over. The electric carriages in those days had large-diameter, solid-tire wheels and full elliptical springs. The center of gravity was high off the ground and care had to be taken not to upset. Sperry had many an embarrassing spill, but he never put a gyro in his automobile. Instead, after a rough trip across the Atlantic he started thinking about a gyro stabilizer for ships at sea. He read everything Dr. Miller had on the gyroscope and sought further information abroad. Later he traced Leon Foucault's original gyroscope of 1850 to the Kensington Museum in London where it had been sent for safekeeping during the

Franco-Prussian War. There he got the curator interested in moving it from its obscure location to a prominent glass case on the main floor near the spot where Foucault's pendulum was swinging out its famous demonstration of the earth's rotation. Sperry wrote the placard for it.

Sperry began by using toy gyroscopes on a homemade model of a ship stabilizer. This he soon replaced by a larger model mounted on a pendulum. He then designed a ship stabilizer, employing an electric motor to control the precession of the gyro so as to keep the stabilizing force in phase with the rolling of the ship. He interested Naval Constructor David W. Taylor, later Chief Constructor of the U. S. Navy. Together they developed experimental apparatus that seemed successful in tests at the Ship Model Basin in Washington. Sperry then received an order from the Navy to stabilize the destroyer *Worden*.

Sperry undertook two other installations—one for the naval transport *Henderson*, the other for the *Osborne*. A larger stabilizer was constructed for the Japanese airplane carrier *Hosho*, and a still larger installation, comprising three gyros, for the 35,000-ton *Conte di Savoia* of the Italian Line. Several large yachts also were fitted with gyro stabilizers, but the equipment proved to be too expensive. The extra weight, expense and maintenance difficulties of gyro stabilizers were never fully acceptable to ship operators and Sperry's installations, though quite effective, were not continued.

Gyro Compass

Another possible use of the gyro which began to attract Sperry's interest about 1908 was for a ship's compass. There was urgent need for a compass which would not be subject to the vagaries of the magnetic field on steel battleships. Turning gun turrets shifted the magnetic compass indication sometimes as much as twenty-five degrees. Foucault had predicted in 1850 that it should be possible to make a gyroscope sense the earth's rotation and point true north. However, he suggested no practical way to accomplish this. In Foucault's time there was no electric motor available to keep the gyro spinning. Sperry saw another opportunity for an electric motor, first, to

spin the gyroscope and, secondly, as a chaser to turn the top end of Foucault's suspension wire to keep it in alignment with the gyro element as the ship turned in its course.

As Sperry was tied up with the detinning process for the American Can Company, his ship stabilizer, and other activities, he called in his friend Hannibal C. Ford, an extremely clever designer of intricate apparatus. Ford and Sperry together started on the design of a gyro compass in a rented work room at 18-20 Rose Street, New York. As a sideline they designed a small gyro stabilizer for an airplane then being built by Stanley Y. Beach of the *Scientific American*.

By the spring of 1910, there was so much going on with gyros for compasses and for ship stabilizers that Sperry decided to form another company to take over gyro work. On April 19, he rented larger quarters at 40 Wall Street and formed the Sperry Gyroscope Company. The detinning process was now in full operation at Carteret, New Jersey, and Sperry was able to devote full time to the new company. There was no outside financing; Sperry put in the cash he had received from the American Can Company and sold all of his securities except the Goodman stock, whose dividends supported his family.

By 1911, his first gyro compass was ready for sea trials. After a preliminary run from New York to Norfolk on the *Princess Anne* of the Old Dominion Line, the compass was delivered to the U.S.S. *Delaware*. Hannibal Ford went aboard to superintend the installation, and Sperry joined him later to witness the tests. By the time the tests were completed, the Navy had two gyro experts, Lieutenant R. E. Gillmor, who mastered the theory, and Chief Electrician Thomas A. Morgan, who made the compass operate. The tests were successful and soon Sperry had a trial order for four gyro compasses. Business prospects for this new scientific gadget looked good and more help was needed. Gillmor and Morgan resigned from the Navy to join Sperry. Within a year Gillmor had a London office and was demonstrating the gyro compass before the Admiralty and the Royal Society. Sperry rented space near the Navy Yard in Brooklyn to produce compasses. Soon Morgan was installing the new compasses on battleships, cruisers.

and submarines of the British, French, Italian and Russian navies. Trials were in progress on a German naval vessel at the outbreak of World War I. The engineer in charge had to get off in a hurry and leave the instrument on board.

The effect of World War I on the demand for Sperry's gyro compass was enormous. The instrument grew in importance with every sea engagement. The Sperry Gyroscope Company was overwhelmed with the task of equipping simultaneously the United States Navy and the allied fleets. Sperry borrowed money from the Bank of America and built a large factory at Manhattan Bridge Plaza, Brooklyn, in 1915-16, and the Sperry Gyroscope Company, Limited, was formed in London with Gillmor as managing director to build gyro compasses for the British and other allies.

Later the gyro compass was arranged to control the steering engine so as automatically to hold a ship on any predetermined course. This "Metal Mike" was in fact a robot helmsman more capable of sensing and correcting small deviations from course than any sailor and, furthermore, without the usual human limitations due to fatigue and exposure.

Gun Fire Control

While waiting for the *Delaware* to return from the coronation of King George V, Sperry arranged with the Bureau of Ordnance of the Navy to have his gyro compass installed on the U.S.S. *Drayton* in order to demonstrate the possibility of using a repeater compass in the plotting room to indicate the true heading of the ship. The ordnance experts liked the electrically connected repeater compass, and asked Sperry to make a further connection with a telescope above decks to indicate the angle that the target bore from the bow of the ship. Sperry put a target-bearing pointer on top of the repeater compass dial, so that target bearings, as well as the true heading of the ship, could be read off.

Admiral Joseph Straus, Chief of Naval Ordnance, urged Sperry to observe target practice and to examine the basic fire control problem of long-range guns. He found in Sperry a man who not only grasped the problem instantly, but who could

propose a solution. This was the start of another fruitful field of invention and design for Sperry which he carried out over the years with successive Chiefs of Naval Ordnance; Earle, Fiske, Sypher, Overstreet, etc.

A new concept of gunfire control was evolved by Sperry and the U. S. Navy ordnance experts. The entire battery should be operated as a single unit and directed in both elevation and train from one sighting point. To this end Sperry devised an accurate electrical system for transmitting to all guns the proper angles of elevation and train, introducing the necessary corrections automatically from instruments located in the plotting room below decks. Finally, the whole battery must be fired in salvo by one officer in the top controlling the firing. The gyro compass came into the system to keep the guns trained on the target at all times, irrespective of course changes. The various electrical and mechanical elements working in combination as a system required an over-all precision of operation never before thought possible. Sperry's fire control system was installed during World War I on all of the battleships of the United States Navy—some thirty in number.

After World War I Sperry in collaboration with the Army Ordnance Department developed a mobile anti-aircraft fire control system. Searchlights and sound locators (now replaced by radar) were added to take care of the difficult night phase of the problem.

Airplane Automatic Pilot

In 1913 conditions seemed ripe for resuming the airplane stabilizer work started but discontinued in 1910. Sperry knew Glenn Curtiss at the Aero Club in New York, got in touch with him, and arranged to send his son Lawrence to Curtiss's shop at Hammondsport. Lawrence Sperry had already built and flown his own airplane and later was awarded F.A.I. Pilot's License No. 11.

This time Sperry's approach to the airplane stability problem was different. Instead of counting on direct gyro-stabilization of the airplane, he devised a gyro unit which held only itself stabilized in the horizontal plane. From this unit, electrical contacts actuated the clutches of servo-motors which in turn

operated the ailerons and elevators of the airplane as a human pilot would.

The Aero Club of France announced an international competition for a safe airplane with a prize of 50,000 francs to be awarded to the winner. Curtiss, in whose flying boat the gyro stabilizer had been tested, persuaded Sperry to send Lawrence to Paris to compete for the prize. The demonstration flight was made in June 1914.

As the plane flew low past the judges' stand the mechanic climbed out on the wing and Lawrence stood up in the open cockpit raising both hands above his head. This was indeed convincing; nothing like it had ever been seen before. He won the prize.

Unfortunately for Sperry, during World War I an airplane stabilizer was not wanted. Aerial combat was a "dog fight," each pilot trying to out-maneuver his adversary. Stabilization was the last thing he needed. While the airplane gyro-stabilizer had no active part in the war, under the cloak of military secrecy it was applied to an experimental "aerial torpedo," fundamentally similar to the German V-1 of 1943—twenty-five years, or one World War, ahead of its time.

Aircraft Instruments

The ship's gyro-compass was too big and heavy for an airplane, and moreover a fast airplane flying west at our high northerly latitudes can interfere with the effect of the rotation of the earth in making the gyro point north. Sperry took a license to build a British magnetic compass but encountered difficulty with the so-called Northerly Turning Error. When a pendulous compass card is tilted by centrifugal force in a turn, the dip of the earth's magnetic field causes the compass magnets to turn the card so as to indicate to the pilot a turn in the direction *opposite* to that in which he is actually turning. Pilots caught in a fog were being killed from a spiral dive into the ground.

Sperry solved the problem in 1917 by the invention of perhaps the greatest flight safety instrument in the history of

aviation—his Gyro Turn Indicator. Flying straight courses by means of the turn indicator kept the pendulous compass card level and reliable. A little practice even enabled a pilot to turn to and hold any desired course. To this instrument was later added a ball in a curved tube as a bank indicator to become the Turn and Bank Indicator. Later the Directional Gyro and the Gyro Horizon were added to form the nucleus of a group of flight instruments in use on every airplane flying today. James H. Doolittle was the first to put this combination together, and by using it in addition to local radio beams, made history in September 1929 by making the first "blind" take-off, flight and landing of an airplane.

While the gyro-stabilizer as such did not find application directly to the airplane, it soon re-entered the picture in the form of the Sperry auto-pilot. This instrument used a combination of gyroscopes to control servo-motors to operate the three controls of the airplane to hold it on a desired flight path. It was the forerunner of all automatic pilots to follow, and has become standard equipment on all large airplanes, both civil and military.

New Corporations

Sperry the inventor was frequently forced by his success to become Sperry the promoter. Engineering and manufacturing help, and always money, had to be found. In a few instances he could sell his patent rights to established concerns, as in the cases of his storage battery and his electro-chemical processes. But his major inventions required the development and marketing of an entirely new product. For this a new company had to be financed and staffed. A dozen or more Sperry concerns were set up, of varying degrees of vitality, the principal one being, of course, the Sperry Gyroscope Company.

The success that Sperry was having as an inventor prompted some of his young assistants to go into business for themselves after World War I. Hannibal Ford left to form the Ford Instrument Company, and Mahood and Davis founded the Arma Corporation. Colvin, Titterington, and Goldsboro left to form the Pioneer Instrument Company, and Carl Norden

established Carl L. Norden, Inc. to make a bomb sight and to undertake other ordnance developments.

In 1925, Sperry, not wishing to load the Sperry Gyroscope Company with his inventions that were unrelated to products of that company, started the Sperry Development Company, changed in 1930 to Sperry Products, Inc.

In 1928 when Sperry was sixty-eight years old his health began to fail. In that year the Sperry Gyroscope Company was sold to his good friend C. M. Keys, who put it into the North American Aviation Company, together with Curtiss-Wright and several other airplane concerns. After the financial crash of 1929, T. A. Morgan, then president of Sperry Gyroscope Company, became president of North American Aviation, and reorganized it by separation into three independent corporations; Curtiss-Wright, North American Aviation including Eastern Airlines, and the Sperry Corporation. Into the last he put the Sperry Gyroscope Company, later adding Ford Instrument Company, Waterbury Tool Company, and Vickers Hydraulics, Inc. Sperry Corporation is now a large publicly owned enterprise, listed on the New York Stock Exchange and employing thousands of people.

It is of interest to note that T. A. Morgan, R. E. Gillmor, and Preston Bassett, who had joined Sperry in his pioneering days, continued in active leadership of the Sperry enterprises.

Morgan retired in 1952, as Chairman and President of the Sperry Corporation, after forty years of service. Gillmor, now Vice-President of the Sperry Corporation, was succeeded as President of the Sperry Gyroscope Company by Bassett.

Sperry, though relieved of major business responsibilities, could not slow down. His inventive mind was too active. He resumed previous work on a compound supercharged Diesel engine, an automatic transmission for automobiles, a variable-pitch propeller for airplanes, an automatic railroad track inspection apparatus and a rail flaw detector. The last two constituted his major interest in the last two years of his life.

Track Recorder Gyro

In 1929, President Hoover, after a reception at the White House, sent off the U. S. delegates to the World Engineering Congress in Japan. At Chicago their special train was transferred to the Santa Fe where they were handed a mimeographed announcement:

"It is assumed that we are all familiar with the intimate connection that our Chairman, Mr. Sperry, has for many years had with the gyroscope. It is, however, probably not known generally that one of the uses that he had worked out is the application of the gyroscope to railroading.

"This application relates to placing inspection of road bed and track on a strictly scientific basis. . . . The gyroscope gives an accurate and dependable base line against all movements of the car body. . . . The outstanding feature of this method of track inspection is that the service is performed under full-load conditions, . . . instead of relying on the inspector's judgment of the condition of the road bed after the loads have passed and the tracks have sprung back. . . .

"The excellent condition of the road bed on the Santa Fe lines . . . is measurably due to this novel scientific aid. . . .

"As a special courtesy to the engineers en route to the Tokyo Congress, this car has been taken out of service and will be attached behind the train for two hours out of Kansas City. . . .

W. B. Story
President"

Rail Flaw Detector

As a result of increasing axle loads, small internal cracks, not visible to inspection from outside, were growing in proportion to the tonnage of trains passing over the tracks, frequently causing a break and derailment. Many schemes for detecting fissures in track were being tried. Sperry reviewed everything that was being developed, especially a magnetic method. He correctly guessed or intuitively knew that a small fissure, because the opposing faces were so close together, would not hinder the flow of magnetism nearly as much as it would the flow of a low-voltage current. Sperry told his railroad friends he thought an electric current method offered promise.

Sperry appeared before the Rail Committee of the American Railroads Association in 1926 and offered to set up laboratory

equipment and to make tests. The A.R.A. supplied rails from all parts of the country for test. Sperry bought a 2,000-ampere, 6-volt generator and tested the rails, marking the locations of fissures. The rails were then broken in the presence of a committee which reported a perfect score for Sperry. In October 1927, the A.R.A. commissioned Sperry to put his laboratory equipment on a car, and to test rails in track. The car was run over a test track made up of fissured rails at Beacon, New York, but the car did not notice any fissures. The method that had worked so well in the laboratory would not work under normal track conditions. A film of oxide and dirt rolled into the surface of the rail made it impossible for the low-voltage contacts to work reliably. But failure had come to Sperry before and he quickly devised a new scheme for detecting the fissures. The principle of passing a direct current through the rail was retained, but contact brushes for the indicator were replaced by small search coils riding above the rail in the magnetic field surrounding the rail. A fissure in the path of the heavy current would distort the magnetic field around the rail, thus inducing an electric potential in the moving search coils. This potential was amplified and recorded on a tape synchronized with the rail while a spot of paint was sprayed on the rail to show the location of the defect.

This detector car was hailed by the Bureau of Safety of the Interstate Commerce Commission as the greatest advance in the safety of railroading in sixteen years.³ Sperry was "in the hole" financially about one hundred thousand dollars.

At the time of Sperry's death in 1930 Sperry Rail Service was operating ten cars. Now twenty cars are in operation, testing annually 160,000 main line miles in the United States and Canada. Altogether over one-million defective rails have been located in two million miles of track as a result of Sperry's invention and its reduction to practice through business enterprise. It is noteworthy that still another going business was created by Sperry after his apparent retirement at the age of 68.

³ I.C.C. Report, 1927, pp. 90-91.

Naval Consulting Board

During World War I Sperry was an active and enthusiastic member of Thomas A. Edison's Naval Consulting Board and served as chairman of three of its committees: Aeronautical, Mines and Torpedoes, Aids to Navigation.

Sperry may not have been a very good committee chairman and it is likely that he supplied more ideas than could ever be developed by his committees. It is recorded that Sperry proposed schemes for an optical range indicator, an electrically driven torpedo gyro, a buoy to announce by radio the near presence of a submarine, an airplane gun sight, a device for determining the range for fuse setting and for target altitude and azimuth, and a bomb sight and automatic bomb dropper with gyro-stabilized equipment.

He assisted in the development of improved depth bombs for use against enemy submarines and his company manufactured 10,000 of them. He also raised the power of his own anti-aircraft searchlight to some two-billion candle power. It was visible as a beacon light for 100 miles.

His service to the Navy was summarized by Secretary Charles Francis Adams in these words:

"His numerous inventions, including his gyro compass, airplane stabilizer, high intensity searchlight, and his apparatus for accurately controlling the fire of our guns, have assisted materially in placing the Navy in first class fighting trim. It is safe to say that no one American has contributed so much to our naval technical progress."

Honors and Awards

Sperry was a frequent contributor to the proceedings of engineering and scientific societies both here and abroad. He was a founder member of the American Institute of Electrical Engineers, the National Electric Light Association, and the American Electrochemical Society. He was a member of the Society of Automotive Engineers, Society of Naval Architects and Marine Engineers, American Chemical Society, American Petroleum Institute, and the American Physical Society. He

served as chairman of the Division of Engineering and Industrial Research of the National Research Council, president of the New York Electrical Society and of the American Society of Mechanical Engineers. He became a member of the National Academy of Sciences in 1925.

Sperry was an enthusiastic joiner. He was an active member of the Aero Club of America, the National Aeronautic Association, the Japan Society, the Edison Pioneers, the Engineers Club, the American Association for the Advancement of Science, Sigma Xi, and Tau Beta Pi. He was an honorary member of several foreign professional societies and was always interested in the Baptist Church, Y.M.C.A. and other social groups.

Medals and awards were received at expositions for arc light systems, mining machines, and trolley cars. He received two medals from the Franklin Institute—the Franklin Medal in 1914 and the Elliott Cresson in 1929. He received the Grand Prize of the Panama-Pacific Exposition for his gyro compass in 1915; the Collier Trophy in 1915 for his drift indicator and in 1916 for his turn indicator; the Scientific American Medal in 1915; the Czar of Russia's Decoration for Navigating Instruments; the Order of the Rising Sun in 1922 and the Order of the Sacred Treasure in 1929 from the Emperor of Japan. He received the John Fritz Medal of the United Engineering Societies in 1926; the Holley Medal of the American Society of Mechanical Engineers in 1927; and the first Gary Medal of the American Iron and Steel Institute in 1929 for his fissure detector. He was honored by Stevens Institute, which conferred on him the degree of Doctor of Engineering, *honoris causa*, and by Lehigh University and Northwestern University, each of which awarded an honorary degree of Doctor of Science.

Personal Notes

Sperry's lifelong abstemiousness stemmed from his strict Baptist upbringing. He maintained that the church and the people one met there gave a boy a good start in life, mentioning with pride members of his own Sunday School class, among whom were Chester and Theodore H. Wickwire of the famous wire works; Judge Alton B. Parker, Democratic candidate for

the presidency of the United States; Judge Edward B. Thomas of the Supreme Court, New York State; and Charles H. Duell, Commissioner of Patents.

When Sperry presented a letter from his pastor in Cortland to the Deacon of the Baptist Church in Chicago, he was asked to come back next Sunday after the service and meet some of the people. This he did, and among them was the Deacon's daughter. Before long Sperry was teaching a Sunday School class in a most original fashion, giving talks on all sorts of subjects including lighting and electricity. In addition to his regular classes, he held special meetings to which he invited boys from outside the church. Many of these boys joined the Sunday School. One of the most faithful members was a boy named Eddy Foy, who had become acquainted with the class through a group of newsboys. Years later, whenever Sperry saw Foy's name on a theater marquee, he would duck in at the stage door to be noisily welcomed by the actor in his dressing room.

Mention has been made of Sperry's meeting the Deacon's daughter in Chicago, Zula Augusta Goodman. They were married in 1887 and had four children, Helen (Mrs. Robert B. Lea), Edward (deceased), Lawrence (deceased) and Elmer. Sperry was fortunate in his marriage to a woman gifted with the imaginative capacity to go beyond her own life and experience, together with a wise tolerance for the intensive drive of her partner. To him she often read aloud many hours a day especially during their summers at Bellport, Long Island. This was Sperry's greatest relaxation. He liked biographies, novels and detective stories. There is a painful family recollection of other readings on electrochemistry and detailed patent specifications, followed from a, b, c, etc., down to the triple z on the drawing.

Mrs. Sperry's quiet sympathy and encouragement were important when frustration and doubt plagued the inventor and when business reverses plagued the promoter. Her joy when a brain child really flourished must have been rewarding. Sperry's greatest reverse, to which he never became reconciled, came

from the loss in 1923 of his son Lawrence, flying alone over the North Sea in an airplane of his own design.

Sperry outwardly always seemed supremely self-confident and optimistic. His times of discouragement were known only to very few. He was five feet eight inches tall, weighed about 140 pounds, had light hair, high forehead, clear blue eyes and well-shaped Yankee nose. He was energetic and quick in manner and unusually attractive.

Sperry traveled a great deal and knew practically everyone in the electrical industry both here and abroad. Edison liked to tell of an incident in 1890. Edison and Sperry were watching a large generator being started up in the Edison Power Station on Varrick Street, New York. As the switch was thrown in, sparks flew. Sperry immediately saw what was wrong, took off his coat, and with the help of a dazed young engineer changed the connection of a field coil. Edison made Sperry an honorary member of his Edison Pioneers, and whenever possible Sperry attended their annual celebrations.

Sperry was a prodigious worker. He organized his time not to be idle, and to this end he redesigned his slide rule so that it could be carried in his vest pocket at the end of his watch chain, available at all times. The scale, complete with roots, powers, and trigonometric functions, was spiralled three times around inside a circular case. A two-foot folding rule from Keuffel and Esser Company, the maker and marketer of his circular calculator, together with one of his small notebooks—which numbered 76 at the time of his death—completed the pocket equipment for work on ideas while traveling or wherever he happened to have an idle moment. Occasionally in church, he was tempted to steal a twist of the dail on his calculator. After he moved to Brooklyn, however, he frequently went to hear Dr. Cadman or Dr. Fosdick, and on these occasions he was attentive.

The *New Yorker* in its "Profile" of April 19, 1930 observed: "Although the traits of the inventor are strong in him, Sperry has none of the eccentricities common to the species. Had not an insatiable curiosity etched a kind of quizzical alertness on his face, he would have all the surface characteristics of the

conventional successful American. He is well tailored. His white hair and mustache give the required distinction; but his eyebrows are permanently raised in blended wonder and pleasure."

When he went to the theater, it was to see his favorite performers rather than the show, but he was a very responsive and enthusiastic playgoer. Whenever Sperry needed a rest—or when his assistants did—Mrs. Sperry would persuade him to stay over a few days at Bellport, or she would plan a trip to Pinehurst or Hot Springs. There, between golf games, she would act as her husband's secretary, and his assistants back in the shop would receive highly technical instructions in her lovely handwriting. Sperry liked golf, although, with his unorthodox swing, he could not drive 150 yards. However, the ball invariably went straight.

Sperry had an electrical man's amateur enthusiasm for engines in which he indulged himself almost all his life. Ideas for engine improvements kept cropping up from time to time, and in the aggregate he spent a fortune on them. He built and tested several versions of a compound supercharged gas engine and then converted it to the Diesel cycle. At engineering society meetings he entered vigorously into discussions on engines. According to an assistant, Ralph Boyer, who later became chief engineer of the Cooper-Bessemer Company, Sperry contributed greatly to the perfection of the solid fuel injection system for Diesels which is in general use today. For a nominal sum he licensed the General Electric Company and the Government on his supercharger patents, and when asked about the cost of this development he said with a broad smile, "Financially it was just an inventor's bad dream."

He never cared for luxuries and lived at home on about the scale of a well-paid Baptist minister. That was the sort of environment he liked.

His attitude toward his work is best described in his own words:

"... My work, which has been practically continuous, never much considering hours, times, or places, has been a source of the keenest joy; and even though it may not have led to the

goal desired it has always led somewhere and added to both experience and caution in pushing forward. In the thrill of the work itself I have always felt that I have had my share of reward. From time to time, often after long periods of research, patient experimentation, and repeated changes, there have come great satisfactions. On such occasions there comes over me a welling up from within, a sort of elation, and life takes on a new and exalted aspect. This is living! These have been my times of reward.”⁴

Summary

Elmer Sperry combined qualities which make for success in any walk of life. He was physically and nervously tough, shrewd and persuasive, intelligent and persistent, modestly self-confident, and above all intensely interested in the world about him.

Acute observation stimulated his imagination and set in train thought processes that repeatedly culminated in important inventions. The concept of an invention led at once to action to create means to develop it to its widest usefulness. He was not academically trained but had no fear of the unknown and knew when and how to get technical advice.

In the National Academy of Sciences, Sperry enjoyed his association with men of science but modestly questioned his own credentials for membership. Nevertheless, he persuasively and fortunately for the reputation of the Academy, successfully, advocated the election of Edison who said he knew no science and was glad of it.

Sperry took great satisfaction in his sense of participation in the classic experiments of Albert A. Michelson to determine the velocity of light. Sperry had supplied the equipment, including a Sperry superpowered searchlight.

It is significant that Sperry was never a garret-starved inventor waiting for recognition. His ideas became his enterprises, his enterprises became under his management successful businesses, to be placed in due time in the hands of competent and substantial foster parents.

Elmer Sperry had the gift of attracting to himself brilliant collaborators who advanced his ideas and carried them forward

⁴From response on receiving the John Fritz Medal, December 7, 1926.

to generous fruition. His inventions and enterprises opened new fields of industrial activity which now give employment to tens of thousands.

He was inventor, promoter, manager, salesman and trader. In every role he had friends to help him. No man in our complex civilization is alone sufficient; he lives and grows in his environment. Elmer Sperry was supremely well adapted to his environment at the dawn of the electrical age, fortunate in his wife and family, and in his associates and friends.

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

- Amer. Electro. Soc. Trans.=American Electrochemical Society Transactions
 Amer. Inst. Elec. Eng. Trans.=American Institute of Electrical Engineers Transactions
 Amer. Soc. Mech. Eng. Trans.=American Society of Mechanical Engineers Transactions
 Elec. Jour.=Electrical Journal
 Elec. Rev.=Electrical Review
 Elec. World=Electrical World
 Franklin Inst. Jour.=Franklin Institute Journal
 Mech. Eng.=Mechanical Engineering
 Proc. Eng. Club Phila.=Proceedings, Engineers' Club of Philadelphia
 Sci. Amer.=Scientific American
 Sci. Amer. Mo.=Scientific American Monthly
 Soc. Auto. Eng. Trans.=Society of Automotive Engineers Transactions
 Soc. Naval Arch. Marine Eng. Trans.=Society of Naval Architects and Marine Engineers Transactions

LIST OF THE MORE IMPORTANT SCIENTIFIC PAPERS OF
 ELMER AMBROSE SPERRY

1885

- The best form of dynamo. Elec. World, 6, 87-88. Paper read before the National Electric Light Association, August 29, 1885.

1890

- Operation of electric motors with high tension currents. Elec. World, 15, 112-113. Abstract of paper read before the Chicago Electric Club.
 Duplex gas engines. Elec. World, 16, 198.

1892

- Electricity in bituminous mining. Amer. Inst. Elec. Eng. Trans., 9, 374-400.

1893

- Traction and street railway trucks; more data on traction experiments. Elec. World, 22, 413.

1899

- Electric automobiles. Amer. Inst. Elec. Eng. Trans., 16, 509-525.

1900

- Automobiles as a source of revenue for central stations. Elec. Rev., 36, 596, 608-610. Paper read before the National Electric Light Association, Chicago, May 24, 1900.

1903

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1906

Electrochemical processes as station load equalizers. Amer. Electro. Soc. Trans., 9, 147-152.

1908

Utilization of power stations for electrochemical and electrothermal processes during periods of low load. Amer. Electro. Soc. Trans., 14, 259-261.

1910

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1912

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1913

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Engineering applications of the gyroscope. Franklin Inst. Jour., 175, 447-482.

Some graphic studies of the active gyro stabilizer. Soc. Naval Arch. Marine Eng. Trans., 21, 181-187.

1915

Recent progress with the active type of gyro stabilizer for ships. Soc. Naval Arch. Marine Eng. Trans., 23, 43-48.

1916

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1917

Aerial navigation over water. Soc. Auto. Eng. Trans., 12, 153-165.

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1919

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1920

Non-rolling passenger liners. Sci. Amer. Mo., 1, 232-237.

Golf without a caddy. Sci. Amer., 123, 473.

1921

- The gyro stabilizer for ships. *Elec. Jour.*, 18, 335.
 What the Virginia Capes aircraft bombings show. *Mech. Eng.*, 43, 624.
 Compounding the combustion engine. *Amer. Soc. Mech. Eng. Trans.*, 43, 677-716.

1922

- Automatic steering. *Soc. Naval Arch. Marine Eng. Trans.*, 30, 53-57.

1923

- The automatic pilot. *International Air Congress Report*, London, 406-413.
 The high intensity light in night aviation. *International Air Congress Report*, London, 816-821.
 A substitute for gasoline that will not burn. *International Air Congress Report*, London, 602-605.
 Sperry gyro turn indicator. *International Air Congress Report*, 404-405.

1927

- The light supercharged Diesel engine for use in air service. *Mech. Eng.*, 49, 723.

1928

- The non destructive detection of hidden flaws. Prize-winning paper, Year-book of *Amer. Iron & Steel Inst.* for 1928.

1929

- Aeronautics and arbitration. *U. S. Air Service*, 14, 37.

LIST OF E. A. SPERRY'S PATENTS

<i>Year</i>	<i>Date</i>	<i>Number</i>	<i>Description</i>
1882	June 27	260,132	Dynamo Electric Machine.
	Aug. 1	261,965	Armature for Dynamo Electric Machines.
	Sept. 5	263,982	Vehicle Wheel.
	Oct. 17	266,956	Valve for Steam Engines.
	Dec. 12	268,956	Dynamo Electric Machine.
1883	Oct. 16	286,970	Combined Annunciator and Alarm System.
1884	Feb. 26	294,092	Machine for Cutting Screw Threads.
	Apr. 29	297,866	Electric Regulator.
	Apr. 29	297,867	Commutator and Brush for Electric Machines.
	July 1	301,175	Regulating Device for Electric Lamps.
	Sept. 9	304,966	Electric Arc Lamp.
1886	June 15	343,651	Vitrified Asbestos.
	Dec. 7	353,986	Regulator.
	Dec. 7	353,987	Motor.
	Dec. 7	353,988	Regulator for Dynamo Electric Machines.

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<i>Year</i>	<i>Date</i>	<i>Number</i>	<i>Description</i>
1886	Dec. 7	353,989	Armature.
	Dec. 7	353,990	Regulator.
	Dec. 28	354,945	Dynamo.
	Dec. 28	354,946	Dynamo.
1887	Mar. 29	360,060	Electric Car Brake.
	Apr. 26	361,843	Apparatus for Distributing Power.
	Apr. 26	361,844	Safety Device for Incandescent Lamps.
	Aug. 30	369,036	Lightning Arrester.
1888	July 17	385,184	Electric Railway.
1889	Jan. 22	396,439	Electrical Switch.
	Feb. 19	397,945	Electric Battery.
	Feb. 26	398,668	Regulator for Dynamo Electric Machines.
	Mar. 26	400,264	Automatic Grounding Device.
	June 11	405,187	Electric Drilling Machine.
	June 11	405,188	Electric Mining Machine.
	June 18	405,440	Electric Arc Lamp.
	June 18	405,441	Dynamo.
	Dec. 17	417,290	Galvanic Battery.
	Dec. 31	418,245	Gas Pressure Regulator.
1890	Jan. 7	418,824	Lightning Arrester.
	Jan. 28	420,117	Electric Regulator and Motor therefor.
	May 27	428,787	Pick for Mining Machines.
	Aug. 5	433,551	Gas Engine.
	Aug. 12	434,096	Rotating Part of Dynamos and Motors.
	Aug. 12	434,097	Power Gearing for Vehicles.
	Aug. 12	434,098	Power Gearing for Vehicles.
	Aug. 12	434,363	System of Transportation in Mines.
1891	Feb. 10	446,030	System of Electrical Distribution for Mines.
	Feb. 10	446,031	Electric Switch.
	June 9	453,822	Commutator.
	June 23	454,500	Mining Machine.
	July 7	11,177	Power Gearing for Vehicles (reissue).
	Sept. 15	459,596	Mineral Drilling Machine.
1892	Jan. 12	466,807	Electric Trolley.
	Jan. 12	466,808	Truck for Vehicles.
	Mar. 1	469,725	Dynamo Electric Machines.
	Mar. 8	470,516	Electric Locomotives.
	Mar. 22	471,151	Trolley Wire Support.
	June 7	476,426	Electric Generator and Motor.
	June 7	476,570	Fuse Block for Electric Circuits.
	July 5	478,138	Electric Mine Car.
	July 5	478,139	Electric Locomotive.
	July 5	478,140	Trolley Wire Splice.

<i>Year</i>	<i>Date</i>	<i>Number</i>	<i>Description</i>
1892	July 5	478,141	Mining Machine.
	July 5	478,142	Dynamo Electric Machine or Motor.
	July 19	479,029	Electric Arc Lamp.
	July 19	479,030	Armature for Electric Machines.
	Aug. 9	480,525	Electric Arc Lamp.
1893	May 23	497,832	Electric Mining Machine.
	July 11	501,194	Revolving Armature for Electric Machines.
	July 11	501,195	Electric Locomotive.
	July 25	501,968	Electric Railway Trolley.
	July 25	502,020	Electric Locomotive.
	Aug. 15	503,443	Trolley Wire Switch.
	Oct. 3	505,994	Electro-conducting Bearing for Trolley or other Wheels.
	Nov. 28	509,776	Electric Controller.
1894	Jan. 16	513,062	Automatic Regulator for Dynamo Electric Machines.
	Feb. 27	515,374	Electric Controller.
	June 5	520,822	Electric Brake (acquired from C. E. Davis).
	Sept. 4	525,394	Controller for Electric or other Motors.
	Sept. 4	525,395	System & Apparatus for Control of Electric Vehicles.
1895	Feb. 26	534,676	Clutch for Shafts.
	Feb. 26	534,974	Electric Brake.
	Feb. 26	534,975	Apparatus for Arresting Motion of Electrically Propelled Mechanism.
	Feb. 26	534,976	Car Wheel.
	Feb. 26	534,977	Electric Brake.
	Mar. 5	535,303	Motor Truck.
	Mar. 5	535,304	Mounting for Electric Motors.
	Mar. 12	535,511	Electric Controller.
	Apr. 9	537,130	Arc Rupturing Device.
	Sept. 10	545,920	Power Transmitting Device.
	Dec. 17	551,480	Steam Engine.
1896	Feb. 25	555,291	System of Control for Electric Motors.
	Mar. 31	557,162	Power Transmitting Device.
	May 19	560,375	Power Gearing for Electric Cars.
	May 26	560,658	Controller for Electric Cars.
	June 2	561,354	Power Gearing for Electric Cars.
	June 16	562,100	Controller for Electric Cars.
	June 23	562,498	Power Transmitting Mechanism.
	June 23	562,499	Coupling for Electric or other Power.
	June 23	562,500	Coupling Transmission Device.
	June 23	562,501	Electric Controller.

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<i>Year</i>	<i>Date</i>	<i>Number</i>	<i>Description</i>
1896	July 7	563,424	Mechanical Movement.
	July 7	563,425	Power Gearing for Electric Cars.
	Aug. 18	565,935	Coupling Device.
	Aug. 18	565,936	Power Gearing for Electric or other Motors.
	Aug. 18	565,937	Electric Brake.
	Aug. 18	565,938	Power Transmitting Gearing for Electric R. R. Trucks.
	Aug. 18	565,939	Controller for Electric Railway Cars.
	Aug. 25	566,426	System of Control for Electric Motors.
	Sept. 8	567,418	Power Gearing for Trucks.
	Oct. 13	569,305	System of Control for Electric Motors.
	Nov. 17	571,409	Electric Brake.
	Nov. 17	571,410	Electric Brake.
	Dec. 29	574,120	Electric Car Brake.
1897	Feb. 16	577,081	Electric Controller.
	Feb. 16	577,119	Electric Brake.
	July 27	587,019	Power Transmitting Device.
1898	Dec. 20	616,153	Motor Vehicles.
1899	Oct. 31	635,815	System & Apparatus of Controlling Electric Vehicles.
	Oct. 31	635,816	System & Apparatus of Controlling Electric Vehicles.
1900	Jan. 9	640,968	Electric Vehicle.
	Jan. 16	641,412	System of Electric Circuits and Brakes.
	Feb. 13	643,257	Motor Carriage.
	Feb. 13	643,258	Motor Vehicle.
	Mar. 20	645,902	Motor Gearing.
	Mar. 20	645,903	Motor Vehicle Brake.
	Mar. 27	646,081	Gearing for Motor Vehicles.
	Mar. 27	646,325	Battery Jar or Receptacle.
	Apr. 3	646,922	Storage Battery.
	Apr. 3	646,923	Cellulose Envelope for Elements of Storage Batteries.
	May 8	649,003	Envelope for Storage Batteries.
	May 15	649,491	Electric Storage Battery.
	May 22	649,998	Element for Storage Batteries.
	Oct. 23	660,318	Apparatus for Governing and Controlling Marine and other Engines.
	Oct. 30	660,805	Actuating device for Railway Appliances.
	Oct. 30	660,825	Actuating device for Railway Appliances.
1901		688,749	Storage Battery Tray or Case.
1902	Jan. 14	691,324	Pigment and the Product thereof from Ferrous Liquors.

<i>Year</i>	<i>Date</i>	<i>Number</i>	<i>Description</i>
1902	Mar. 25	696,209	Envelope for Battery Electrodes.
	July 1	703,673	Electric Battery & Mounting same.
	July 1	703,674	Correction for Batteries.
	Nov. 4	713,020	Manufacturing Elements for Storage Batteries.
	Dec. 16	716,125	Electric Railway.
1903	Mar. 24	723,326	Armored Element for Electric Batteries.
	Mar. 24	723,327	Storage Battery.
	Mar. 24	723,328	Storage Battery.
	Mar. 24	723,329	Manufacture of Envelopes for Storage Batteries.
	May 26	729,100	Separator for Storage Batteries.
	June 30	732,130	System of Control for Electrically Propelled Trains.
1904	Jan. 26	750,471	System of Electrical Generation, Distribution and Control.
	Jan. 26	750,497	System of Electrical Generation, Distribution and Control.
	Jan. 26	750,498	Power Transmitting Mechanism.
	Jan. 26	750,499	Power Transmitting Mechanism.
	Jan. 26	750,500	System of Electrical Generation, Distribution and Control.
	Aug. 16	767,604	Frictional Driving Mechanism.
	Oct. 18	772,679	Electric Rackrail.
		772,680	Rackrail for Locomotives.
	Oct. 25	772,971	Rackrail.
	Oct. 25	773,235	Logarithmic Calculator.
	Nov. 1	773,685	Storage Battery Electrode.
	Nov. 1	773,686	Storage Battery.
1905	Feb. 7	781,795	Storage Battery Electrode.
1906	Oct. 23	833,760	Regulating Apparatus.
1907	Apr. 9	849,432	Electric Locomotive.
	Oct. 1	867,436	Lead Pigment and Similar Compounds.
	Nov. 26	872,092	Detinning and Recovering Merchantable Iron from Tin Plate Scrap.
		872,205	Producing Stannic Chloride.
	Dec. 10	873,699	Detinning.
	Dec. 17	873,804	Electric Lighting.
	Dec. 17	874,040	Detinning and Producing Tin Compounds and other Products.
		874,707	Electrolytic Refining of Tin.
	Dec. 31	875,632	Detinning and Producing Tin Compounds and other Products.

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<i>Year</i>	<i>Date</i>	<i>Number</i>	<i>Description</i>
1908	Jan. 21	877,243	Apparatus for making Stannic Chloride.
	Jan. 21	877,244	Purifying Stannic Chloride.
	Jan. 21	877,245	Effecting Reactions.
	Jan. 21	877,246	Effecting Reactions between Solids and Gases.
	Jan. 21	877,247	Making Stannic Chloride.
	Jan. 21	877,248	Making Stannic Chloride.
	Feb. 18	879,596	Reclaiming Tin Scrap.
	Mar. 17	882,354	Making Stannic Chloride.
	Mar. 31	883,500	Detinning.
	Apr. 21	885,391	Apparatus for Effecting Reactions.
	May 12	887,538	Preparing Pure Tin Compounds.
	Sept. 1	897,312	Electric Locomotive.
	Sept. 1	897,796	Preparing Merchantable Iron and Tin Compound from Tin Plate Scrap.
	Oct. 13	901,266	Preparing Merchantable Iron from Tin Plate Scrap.
	Dec. 1	905,602	Dehydrating Moist Chloride.
	Dec. 8	906,321	Preparing Merchantable Iron from Tin Plate Scrap.
	Dec. 29	907,907	Steadying Device for Vehicles.
1910	June 14	961,549	Cathode.
	Aug. 23	967,990	Producing Clear Stannic Chloride Solutions.
1911	No Patents.		
1912	Feb. 27	1,018,591	Valve.
	Dec. 31	1,048,905	Centrifugal Machine.
1913	Sept. 2	1,071,815	Apparatus for Determination of Periodic Motion.
1914	Nov. 10	1,116,855	Electric Heater.
	May 26	1,097,826	Electrolytic Cell.
1915	Apr. 20	1,136,058	System of Power Transmission.
	May 4	1,137,804	Vehicle Control.
	June 8	1,141,985	Gas Engine.
	Aug. 17	1,150,311	Ship Gyroscope.
1916	June 13	1,186,856	Gyroscopic Apparatus.
	Aug. 15	1,194,889	Internal Combustion Engine.
	Oct. 31	1,203,151	Periscope Azimuth Indicator.
1917	Feb. 13	1,215,425	Plotting Indicator.
	May 15	1,226,132	Combustion Engine.
	May 22	1,227,210	Method of Operating Flaming Arc Lights for Projectors.
	July 10	1,232,619	Ship Stabilizing and Rolling Apparatus.

<i>Year</i>	<i>Date</i>	<i>Number</i>	<i>Description</i>
1917	Aug. 14	1,236,993	Gyroscopic Stabilizer.
	Aug. 28	1,238,503	Automatic Gun Pointing.
	Oct. 2	1,242,065	Ship's Gyroscopic Compass Set.
1918	Feb. 19	Re.14,435	Ship Stabilizing and Rolling Apparatus.
	Feb. 5	1,255,480	Gyroscopic Navigation Apparatus.
	Feb. 26	1,257,417	Gearing.
	Aug. 6	1,274,622	Speed and Direction Indicator for Aircraft.
	Sept. 17	1,279,471	Gyroscopic Compass.
	Oct. 22	1,282,133	Electrode Holder for Searchlights.
	Nov. 5	1,283,943	Reflecting Surface for Optical Instruments.
1919	Mar. 4	1,296,439	Multiple Turret Target Indicator.
	Mar. 4	1,296,440	Repeater System for Gyro Compasses.
	Apr. 15	1,300,890	Navigational Instrument.
	Apr. 15	1,301,014	Electric Drive for Gyroscopes.
	Apr. 29	1,302,488	Electric Arc Light.
	Aug. 5	1,312,084	Torpedo Gyroscope.
	Aug. 5	1,312,085	Stabilizing Gyroscope.
	Aug. 26	1,314,157	Electrical and Gyroscopic Apparatus for Torpedoes.
	Oct. 7	1,318,302	Rotor for Gyroscopic Stabilizers.
	Oct. 14	1,318,701	Method of Searchlight Ventilation.
	Nov. 18	1,321,947	Electric Battery.
	Dec. 23	1,325,810	Multiple Expansion Internal Combustion Engine.
1920	Mar. 9	1,333,224	Submarine Net and Method of Laying the same.
	Mar. 9	1,333,238	Means for Tracing and Locating Submarine Boats.
	June 1	1,342,397	Controlling Mechanism for Ships' Gyroscopes.
	June 1	1,342,398	Electrode for Searchlights and Method of making the same.
	Oct. 19	1,356,505	System of Gunfire Control.
	Nov. 2	1,357,827	Method of Operating Electrodes for Searchlights.
	Nov. 9	1,358,258	Stabilizing Gyroscope.
	Nov. 30	1,360,694	Navigational Apparatus.
	Dec. 14	1,362,574	Light Extinguisher for Arc Lamps.
	Dec. 14	1,362,575	Feeding Mechanism for Searchlights.
	Dec. 21	1,362,753	Wind Driven Generator for Aircraft.
	Dec. 21	1,362,754	Cooling and Lubricating System for Bearings.
1921	Jan. 25	1,366,430	Dead Beat Inclinator.
	Feb. 8	1,368,226	Aeroplane Stabilizer.

ELMER AMBROSE SPERRY—HUNSAKER

<i>Year</i>	<i>Date</i>	<i>Number</i>	<i>Description</i>
1921	Feb. 8	1,368,227	Osmotic Diaphragm.
	Mar. 17	1,378,291	Diving and Governing Means for Torpedoes.
	May 31	1,379,881	Arc Striking and Extinguishing Apparatus.
	July 19	1,384,868	Dirigible Gravity Bomb.
	Aug. 9	1,387,018	Lubricating and Cooling System for Gyroscopes.
	Oct. 18	1,393,844	Observation Apparatus for Submarines.
	Oct. 18	1,393,845	Gyroscope.
	Dec. 6	1,399,032	Gyroscopic Roll and Pitch Recorder.
	Dec. 27	1,401,743	Method and Apparatus for Separating Foreign Substances from Lead Matter.
1922	Jan. 10	1,403,062	Correction Device for Repeater Compasses.
	Jan. 17	1,403,876	Trench Searchlight.
	Feb. 21	1,407,491	Turn Indicator.
	Apr. 11	1,412,757	Military Searchlight.
	Apr. 11	1,412,758	Sighting Device for Ordnance.
	May 9	1,415,614	Depth Controlled Mine.
	May 9	1,415,847	Launching Mechanism for Aeroplanes.
	June 6	1,418,335	Automatic Pilot for Aeroplanes.
	July 4	1,421,854	Gyroscopic Apparatus for Torpedoes.
	Aug. 15	1,426,336	Rotor for Gyroscopes.
	Aug. 15	1,426,337	Signalling Apparatus for Detecting Submarines.
	Aug. 15	1,426,338	Visual Signal Means.
	Aug. 15	1,426,339	Wire Wound Gyro Rotor.
	Aug. 29	1,427,560	Means for Detecting Submarine Boats.
	Sept. 5	1,428,507	Wireless Repeater System.
	Oct. 17	1,432,214	Fuel Injection and Igniting Means for Oil Engines.
	Dec. 19	1,439,028	Universally Mounted Searchlight.
1923	Feb. 20	1,445,805	Gyroscopic Navigational Apparatus.
	Feb. 20	1,446,276	Gyroscopic Apparatus for Torpedoes.
	Apr. 17	1,452,482	Means for Governing the Rolling of Ships.
	Apr. 17	1,452,484	Method of Gunfire Control for Battleships.
	Apr. 24	1,452,620	Method of Treating White Lead.
	May 8	1,454,085	Electric Indicator for Vibrations of the Air.
	June 26	1,459,902	Searchlight for the Guidance for Detection of Aircraft.
	Sept. 18	1,468,330	Synchronous Transmission System.
1924	Jan. 1	1,479,630	Cooling Motion Picture Projectors and Films.
	Jan. 15	1,481,248	Automatic Sighting Mechanism for Aircraft Guns.
	Feb. 12	1,483,489	Signalling System for Warships.

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<i>Year</i>	<i>Date</i>	<i>Number</i>	<i>Description</i>
1924	Feb. 19	1,483,992	Means for Spinning up Gyroscopes on Aircraft.
	Mar. 18	1,487,282	Fire Control System.
	June 24	1,499,321	Gyroscopic Compass.
	Sept. 2	1,506,784	Submarine Mine.
	Sept. 2	1,506,785	Gravity Bomb.
	Sept. 23	1,509,267	Aeroplane Gun.
	Oct. 7	Re.15,924	Wireless Repeater System.
	Oct. 14	1,511,240	Cooling Means for Gyroscopes.
	Dec. 16	1,519,272	Mercury Cooling Transfer Valve.
1925	Jan. 13	1,522,924	Position Indicator for Aerocraft.
	Feb. 10	1,515,963	Shoal Water Contact Mine.
	Feb. 24	1,527,932	Alarm Device for Gyro Compasses.
	Apr. 28	1,535,633	Submarine Contact Mine.
	May 12	1,537,713	Drag Rudder for Gravity Bombs.
	Aug. 11	1,548,958	Aviation Beacon.
	Oct. 27	1,558,514	Multiple Gyro Ship Stabilizer.
	Nov. 3	1,560,435	Apparatus for Testing Gyroscopic Compasses.
	Dec. 1	1,563,934	Gyroscopic Inclinator for Aeroplanes.
1926	Apr. 6	1,579,669	Wireless Repeater System.
	Sept. 21	1,600,569	Method of and Means for Balancing Masses.
	Sept. 21	1,600,651	Accelerating Means for Automotive Vehicles.
	Dec. 21	1,611,253	Speed-Measuring Device.
1927	Feb. 8	1,617,310	Repeater Compass.
	Apr. 26	1,626,123	Gyrocompass Relay Transmitter.
	Apr. 26	1,626,363	Gravity Bomb.
	May 3	1,627,210	Valve Mechanism for Combustion Engines.
	May 17	1,629,236	Means for Indicating Loss of Synchronism in Transmission Systems.
	Aug. 9	1,638,417	Ship's Signalling or Broadcasting Device.
	Aug. 16	1,639,062	Piston for Internal-Combustion Engines.
	Sept. 6	1,641,301	Searchlight Cooling and Ventilating Means.
	Nov. 15	1,648,968	Means for Cooling the Pistons of Heat Engines.
	Dec. 6	1,651,845	Gyroscopic Pendulum.
1928	Jan. 24	1,656,962	Synchronizing Mechanism.
	May 15	1,669,882	Searchlight for the Guidance or Detection of Aircraft.
	May 29	1,671,616	Logarithmic Calculator.
	July 17	1,677,305	Two Cycle Supercharging Combustion Engine.
	July 31	1,678,714	Means for Preventing Racing of Ship's Engines.

ELMER AMBROSE SPERRY—HUNSAKER

<i>Year</i>	<i>Date</i>	<i>Number</i>	<i>Description</i>
1928	Aug. 28	1,682,357	Internal Combustion-Engine Cylinder.
	Aug. 28	1,682,358	Combustion-Engine Drive for Ships.
	Sept. 18	1,684,809	Cooling Means for Internal Combustion Engines.
	Oct. 9	1,686,774	Supporting Means for Golf Bags.
	Oct. 23	1,688,403	Piston for Internal-Combustion Engines.
	Oct. 23	1,688,559	Gyroscopic Line of Sight Stabilizer.
	Oct. 23	1,688,691	Transmission System for Automotive Vehicles.
	Oct. 23	1,688,761	Wakeless Torpedo.
	Dec. 4	1,693,966	Oil-Burning Engine.
1929	Jan. 1	1,697,292	Engine and the Transmission of Power therefrom.
	Jan. 15	1,699,379	Method of Refining Crude Fuel Oil.
	Mar. 5	1,704,489	Locking Device for Gyroscopes.
	Apr. 16	1,709,377	Beacon System for Night Flying.
	May 7	1,711,703	Valve Mechanism for Internal-Combustion Engines.
	May 21	1,713,929	Automatic Projector Lamp.
	May 21	1,714,145	Crankless Engine.
	Nov. 5	1,734,353	Automatic Launching Devices for Airplanes.
1930	Mar. 18	1,751,254	Fuel Injecting and Igniting Means for Oil Engines.
	Apr. 22	1,755,340	Director Firing System.
	June 10	1,763,377	Sounding Device.
1931	Jan. 13	1,788,412	Oil Engine.
	Jan. 13	1,788,807	Control Gyro.
	Feb. 17	1,792,937	Wireless-Controlled Aerial Torpedo.
	Apr. 14	1,800,365	Means for Preventing Pitching of Ships.
	May 5	1,803,876	Combustion Engine Locomotive.
	May 5	1,804,380	Fissure Detector for Steel Rails.
	May 26	1,806,652	Automatic Accelerator.
	July 7	1,812,994	Borehole Inclination Recorder.
	Aug. 11	1,818,103	Automatic Pilot.
	Aug. 11	1,818,104	Means for Controlling Dirigible Aircraft.
	Aug. 25	1,820,505	Fissure Detector for Metals.
1932	Nov. 3	1,830,041	Method and Means for Imparting Intelligence.
	Dec. 22	1,837,633	Roadway Inspecting Means.
	Dec. 29	1,838,965	Automatic Steering Device.
	Feb. 9	1,843,959	Track Recorder System.
	Mar. 22	1,850,640	Self-Synchronous Transmission System.
	Mar. 22	1,850,780	Self-Synchronous Transmission System.
	Mar. 22	1,850,978	Recorder for Ships.

NATIONAL ACADEMY BIOGRAPHICAL MEMOIRS—VOL. XXVIII

<i>Year</i>	<i>Date</i>	<i>Number</i>	<i>Description</i>
1932	Apr. 26	1,855,929	Engine.
	July 12	1,867,334	Automatic Steering Mechanism for Dirigible Aircraft.
	July 19	1,867,682	Improvement in Combustion Chamber for Combustion Engines.
	July 19	1,867,683	Combustion Engine.
	July 19	1,867,684	Means for Preventing the Vibration of Crank Shafts.
	July 19	1,867,685	Fissure Detector for Magnetic Materials.
	Aug. 16	1,871,476	Marine Aircraft.
	Aug. 30	1,874,067	Flaw Detector for Irregular Objects.
	Aug. 30	1,874,714	Variable Pitch Propeller.
	Oct. 4	1,880,994	Indicator for Aircraft.
1933	May 2	1,907,014	Variable Pitch Propeller.

REISSUE PATENTS

1932	Feb. 2	18,344	Method of Refining Oil.
	Aug. 2	18,555	Fissure Detector for Metals.

A few years before Sperry died he licensed the government and the General Electric Company for a nominal sum on his basic patent coverage for the art of supercharging internal combustion engines. The basic supercharging patents were 1,141,985 of 1915 and 1,226,132 of 1917.

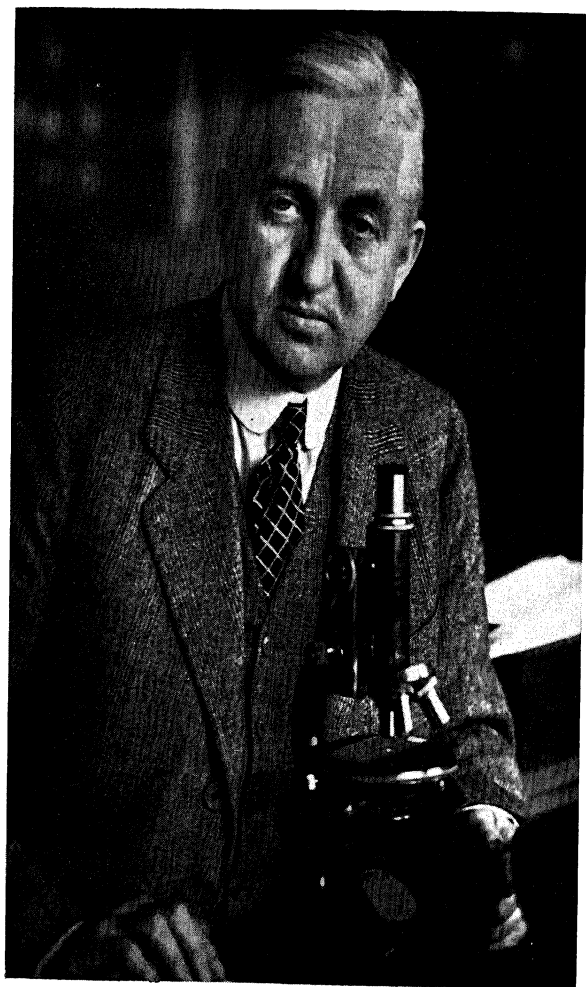
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George L. Strecker

GEORGE LINIUS STREETER

1873-1948

BY GEORGE W. CORNER

George Linius Streeter was generally recognized during the latter years of his life by the embryologists of the world as their leader in the study of human embryology. From 1914 until his death in 1948 he was connected with the Department of Embryology of the Carnegie Institution of Washington, of which he was Director for 23 years (1917-1940). So fully indeed did he plan and lead the work of the Baltimore embryological laboratory that his fame and that of his department are scarcely separable.

Dr. Streeter was born January 12, 1873 at Johnstown in western New York, whither his family, of English descent, had migrated by way of New England. His father was a leader in the chief industry of that region, glove manufacturing. After being graduated from Union College in 1895 he studied at the College of Physicians and Surgeons of Columbia University and took the degree of Doctor of Medicine in 1899. While in medical school his interest in human anatomy was aroused by Columbia's accomplished professor of that subject, George S. Huntington.

After an internship in Roosevelt Hospital, New York City, Streeter became assistant to Dr. Henry Hun, the eminent neurologist in Albany. During two years thus spent in the practice of medicine he served also as demonstrator of the anatomy of the nervous system in Albany Medical College. Intending to become a specialist in clinical neurology, he went to Germany in 1902 to prepare himself for that career by research with the great Frankfurt anatomist, Ludwig Edinger. He also studied with Wilhelm His at Leipzig and was at Berlin for a time. In retrospect it is easy to see that it was His's influence rather than that of Edinger which prevailed with him, for after publishing two papers on his investigation, under Edinger, of the adult brain and spinal cord, and a brief article on neurological technique, he devoted himself irrevocably to

embryology. The first of his Frankfurt articles is an excellent example of the kind of anatomical research into brain structure which was then in progress in many laboratories under the influence of Retzius, Edinger and other Continental neurologists. It is a careful description of the nuclei and fiber tracts in the floor of the fourth ventricle of the human brain, where the VIIth to the XIth cranial nerves originate. The other article describes the spinal cord of the ostrich, which interested Streeter because of the peculiarly large development of that part of the cord which provides innervation for the huge legs of the bird. Although these papers scarcely presage the scope of his later work, they exhibit his lucid style of exposition, his talent for drawing and his precise technique.

Finding himself to be clearly at home in research he abandoned his plans for practice and upon returning to the United States he accepted an invitation from F. P. Mall to join the young department of anatomy at Johns Hopkins Medical School. There he was a member of an extraordinarily able group. Besides Mall himself, the department included Ross G. Harrison, Charles R. Bardeen, Warren H. Lewis, and Florence R. Sabin. Each of these six young scientists was doing important research and all of them were destined to reach distinction. Streeter published in 1904 his first contribution to embryology, on the development of the cranial and spinal nerves in the occipital region of the human embryo. The material came chiefly from Mall's collection. This was descriptive morphology, based on accurate reconstruction from serial sections. For that kind of investigation, which he continued throughout his career, he was particularly fitted by his strong powers of visual construction aided by accuracy in observation and excellent draftsmanship.

During his Johns Hopkins instructorship, influenced no doubt by the example of Harrison and Lewis, Streeter made an excursion into experimental research, studying the results of removing and transplanting the ear vesicles in tadpoles. Although he did not continue, after 1909, the direct study of living embryos by operative methods, these early experiments gave him a permanent appreciation of the fact, sometimes neglected

by morphologists, that an embryo is not merely an incompleated stage in development but is itself a living creature and its component parts are not only "Anlagen" but working organs.

During the three years of his Johns Hopkins appointment he continued to put together the information he had gained from the embryological material placed at his disposal by Hertwig at Berlin, His at Leipzig, and Mall at Baltimore in the study particularly of the development of the internal ear and its nervous connections. This was the beginning of an interest in the development of the human auditory apparatus. He was still writing on this subject as late as 1931 and his researches include a full description of the embryology of the external ear, of the labyrinth and cochlea, and of the whole ganglionic apparatus and the cranial nerves associated with the organs of hearing and equilibration. The monograph of 1918 on the perilymphatic spaces of the labyrinth is a complete and sumptuously illustrated account of a subject on which very little had previously been written. It has been found invaluable by later students in clarifying the relations within the petrous bone.

For one year in 1906-1907 Streeter was engaged in research at the Wistar Institute of Anatomy and Biology in Philadelphia with the rank of Assistant Professor under H. H. Donaldson. In 1907 he was invited to the University of Michigan, where he remained for seven years as Professor in Charge of Gross Human Anatomy and Director of the Anatomical Laboratory.

The pedagogical problems of these years are reflected in Streeter's bibliography by manuals of dissection for medical and dental students, and by a couple of brief papers on embalming bodies for dissection and other technical procedures, but in spite of professorial distractions the even flow of his research continued, with further studies on the development of the ear and of the human brain and peripheral nervous system.

In 1914 his old chief at the Johns Hopkins anatomical laboratory, F. P. Mall, who had just launched the Department of Embryology of the Carnegie Institution of Washington, called him back to Baltimore as Research Associate in the new enterprise. Three years later Mall's untimely death resulted in Streeter's appointment to the directorship. He took over from

his distinguished predecessor a well-organized laboratory and a clear-cut, far-reaching plan of research on all aspects of human embryology. The department already possessed one of the world's largest collections of human embryological material. Under Streeter's guidance Mall's plan was admirably executed and in many respects expanded. The collection grew in size and quality. Talented technical aides, artists, modeler, photographer, and microtometist, were trained to meet his high standards. Not only was the morphology of the embryo studied intensively, but experimentalists like Warren Lewis, Margaret Lewis, Hartman and Metz, and the anthropometrist Schultz were given facilities and encouragement. Twenty-two volumes of the *Contributions to Embryology*, of the Carnegie Institution of Washington (VIII to XXIX), published during his directorship and edited by him, bear witness to the extraordinary productivity of this group under his generous, enthusiastic leadership.

Streeter's personal research for the rest of his life was to a large extent determined by the nature of his post. Mall's program, set forth in his remarkable "Plea for an Institute of Human Embryology" in the *Journal of the American Medical Association*, May 24, 1913 outlined a program of research on what he designated larger questions of human embryology including the curve of growth, development of the external form and internal anatomy of the embryo at successive stages, organogenesis (especially of the brain), histogenesis, the study of embryonic pathology including malformations, the comparative embryology of related species, and experimental embryology to elucidate problems of human development. Comparing Streeter's work published after 1917 with the divisions of the basic plan, it becomes evident that he contributed personally to every major topic on the list except experimental embryology. His work during these three decades can be most clearly described by topics rather than chronologically.

A certain difficulty presents itself to the biographer who attempts to point out the nature of his research, which was characterized by precision rather than by novelty. The achievement was the attainment of such perfection in the study of

material so important yet so difficult to amass and prepare. Streeter was never an explorer of the rough and ready kind. His work contains few totally novel observations, but he possessed supreme ability to take up imperfectly understood phases of embryonic development, refining, integrating, and accurately depicting them. His predilection for this kind of work was founded, no doubt, upon the mental characteristics that went with his exceptional talent for accurate drawing. An intimate associate of his mature years tells how Streeter when examining a new specimen would take pencil in hand and make a free hand sketch so correct that when the younger man afterward made a drawing for the records with the aid of a camera lucida, Streeter's sketch would closely fit the mechanically traced outline. One who draws so precisely has to see the object with perfect comprehension. It was the urge to see and understand, not merely theorize about the unknown transition stages of morphogenesis that made Streeter a great descriptive embryologist.

In fulfillment of this desire he demanded and obtained good material and did not rest until the gaps were filled. His description for example of the development of the labyrinth of the ear, and that of the major internal structures of the brain, in fact all his larger morphological contributions, are so perfectly done that they completely supersede all previous work on those subjects and defy further refinement by methods known at present. Such work is appreciated by experienced colleagues but its content of factual discovery is not readily explainable to the general reader. With these characteristics in mind we may however look with somewhat greater comprehension at the results of his labors.

Mall's first "larger question" pertained to the curve of growth of the human embryo. To answer this question Streeter and his colleagues patiently measured all the embryos and fetuses that came to the laboratory, tabulating the clinical histories, and noting particularly those cases in which the record of gestation age was especially clear by reason of favorable circumstances, e.g. history of a single relevant coitus. When a sufficient number of observations was in hand Streeter published (1920) his

paper on "Weight, sitting height, head size, foot length and menstrual age of the human embryo," accompanied by six charts. This is the classical account of human prenatal growth, to which every embryologist goes when it is necessary to ascertain the age of a fetus or late embryo from its dimensions. At the end of his life Streeter was actively engaged in collating and publishing, in his "Horizons in human development," the information necessary to determine gestation age from physical characteristics in the earlier stages of development, when ordinary dimensions of weight and linear size are not helpful.

The precision of Streeter's tables and curves, and of the pictures of embryos that he chose to accompany them, is so great that the Carnegie embryologists, reporting on clinical specimens, are confidently able to state the age of an embryo within a couple of days, or of a fetus to the exact week, from its general form and dimensions; and even if the specimen has been damaged, its age can still be ascertained with close approximation from the sitting height alone or the foot length or head measurements or from the form of head or hand.

Turning next to the program of studies in the anatomy, organogenesis and histogenesis of the human embryo, here too Streeter made notable contributions. He published admirable descriptions of two very early embryos, the "Mateer" and the "Miller," the latter of which is about 11 days old and was at the time of his paper (1926) the youngest known human embryo. The part Streeter played in encouraging the collection and description of other early human embryos will be discussed later. His study of the developing brain had reached its high point before he became director of the Carnegie Laboratory. Mall probably emphasized brain embryology in his plan because he wanted to get Streeter for his staff. Most of the latter's work on this topic is summarized in his chapter on the nervous system in the Keibel-Mall Handbook of Embryology (1912), which has not yet been superseded as the most comprehensive monograph on the development of the human brain. Streeter also went deeply into the special problem of the development of the blood vessels of the brain (1915, 1918). His other great contribution to human organogenesis, the series of papers on

the development of the internal and external auditory apparatus, has already been mentioned. The "Developmental horizons," which will be specially discussed below, include a careful study of the histogenesis of bone, a valuable review of the development of the human heart and numerous incidental observations on many phases of organ-formation.

Streeter was always interested in the embryological aspects of twinning, and although he wrote little about twin human embryos, his attention to the subject is reflected in the records of the Carnegie Collection with its histories of 300 cases of twin embryos and fetuses; in the extensive memoranda which he gathered from the literature; and in two papers, one on single-ovum twinning in the pig (1924) and the other on the formation of single-ovum twins in man. The latter is based largely on the 17-day Mateer ovum, which contains atypical vesicles then interpreted by Streeter as possibly representing a twin in arrested development, a conjecture which he afterward abandoned.

The Carnegie embryological laboratory has always been much concerned with the pathological aspects of embryonic and fetal development. Even if such problems had not demanded attention on purely scientific grounds, they would have been forced upon Streeter's attention by the duty, assumed by the laboratory, of examining aborted fetuses and malformed embryos, sent in by physicians seeking to know how to avert the loss and distress involved in these domestic tragedies. Franklin Mall and Arthur W. Meyer, who was Mall's scientific executor in this respect, had greatly improved the description and classification of the prenatally dead, retarded, or malformed human being. Streeter turned his attention to analysis of the causes of prenatal damage and to the intensive study of one particular kind of injury, namely local deficiencies resulting from disordered histogenesis. With regard to fundamental causation, the pendulum of thought swung in Streeter's mind to the opposite position from that of Mall, who in his great monograph of 1909, "Causes underlying the origin of human monsters," had emphasized the importance of defective uterine environment. Mall had been influenced by the contemporary work of experi-

mental embryologists who had succeeded in producing maldevelopment of aquatic embryos by placing toxic substances in their environment; Streeter on the other hand was influenced by the more recent work of geneticists on lethal and sublethal genes. Putting together their conclusions with his own reflections he became an exponent of the view lucidly set forth in his Harvey Society Lecture of 1934 that morbid processes in the fetus are largely due to genetic causes.

The pendulum is now swinging back to an intermediate position, in which both genetic and environmental causes are accepted, for still more recent experimental work has proved that embryonic malformation may be brought about by toxic and malnutritional factors of various sorts; but Streeter's skilled exposition was exceedingly valuable in turning the thought of physicians to the importance of genetic factors in human development.

His most significant specific contribution to prenatal pathology is the remarkable article of 1930 on focal deficiencies and their relation to intra-uterine amputation. Infants are sometimes born without a hand or foot, or with a finger missing, but with a well-formed stump like that resulting from a surgical amputation, showing that the missing limb or part had actually developed like its mate, but was subsequently obliterated and resorbed. Still more frequently, aborted fetuses exhibit such intra-uterine amputations, and in these cases there are often adhesions between the amniotic membrane and the amputation stump. In such cases the shriveled limb, not yet fully disorganized, may still be present distally to the adherent amniotic band. Sometimes, even more startlingly, the umbilical cord is found tightly looped about a limb. The latter is deeply grooved by the constricting cord, and may be necrotic beyond the point of constriction. The assumption had always been made that interference with the blood circulation by the adherent amnion, or by the looped cord, is the primary cause of damage to a previously normal part of the body. Streeter, with eyes trained by a vast experience in scrutinizing damaged fetal tissues, perceived that in these cases the amnion becomes adherent to the fetal body where the tissues are already damaged, presumably

by local growth failure due to genetic causes, much as adhesions of the peritoneum or pleura of the adult body are produced by local damage resulting from infection. He showed, furthermore, that loops of the umbilical cord are practically speaking always associated with fetuses that had died in utero before they were aborted; that is to say the looping of the cord is the result rather than the cause of the damage which leads to amputation. In his monograph this revolutionary concept is vigorously explained and demonstrated with a profusion of pictures. The paper well illustrates the basic method by which Streeter's temperament led him to work. The general question came first, namely what do fetal malformations really reveal to careful study? Then came slow painstaking assembly, recording and classification of specimens, until he had seen enough to realize the meaning of small similarities and differences between one specimen and the next. Then a relatively small, or at least closely-defined problem which had become apparent during the exploratory period was selected for intensive study. The records accumulated in years of routine work were placed side by side. Numerous sketches were made. The facts, now apparent to the trained eye, were marshalled with systematic precision. The textual description and exposition was most carefully drawn up, and graphic illustrations by artist and photographer were planned and assembled with convincing thoroughness. The adjective "meticulous," so often used, in ignorance of its etymology, to mean merely careful, correctly describes Streeter's method of work, for he actually seemed afraid to be inaccurate, obscure, or superficial. Another characteristic of his work must be emphasized. This is that the topics of his investigations often seem deceptively narrower than they really were. No one can read attentively the paper on focal deficiencies, or the little masterpiece of observation and exposition on the formation of the filum terminale of the spinal cord (1919) or many another of his works, without being led by his treatment of the specific topic, small as that might seem, toward a strong realization of the general processes of growth and differentiation.

Embryology as Streeter thus developed it was essentially

morphological, and yet was a morphology of living tissues. Taught by his brief period as a practicing physician to see the frame of man as a functioning organism; influenced by his short period of experimentation on living embryos mentioned above, and trained for a time in neurology, that branch of anatomy in which the relation of structure to function is most forcibly apparent, he always tended to visualize the processes of growth and change, even though the embryo under his microscope had long since been permanently preserved, cut into sections and cemented upon glass slides. Walter Cannon's aphorism "A microscope slide is a frozen moment in the flux of life" exactly represents this attitude. Streeter's emphasis on the fact that the detailed structures of an embryo are parts of a living, currently integrated individual, not merely items of a blue-print for the adult, or relics of its evolution, set up in his mind a strong antagonism to that kind of embryology represented in its extreme form by Haeckel's law of recapitulation, which looked at every embryonic structure as if it were merely a record of phylogeny.

His whole attitude on the question of simplification and diagramming in embryology was cleverly summed up in his presidential address "Archetypes and Symbolism" before the American Association of Anatomists in 1927. In this address, discussing the old concept that the vertebrate brain is fundamentally constructed of three vesicles, he said "the brain begins to build its definitive parts before the closure of the neural tube, without going through a preliminary archetypal indifferent three-vesicle stage. With further experience and additional material this has been abundantly substantiated in the pig as well as in man. There seems to be no evidence that the brain wastes any empty gestures toward the past. With no false moves it proceeds directly with the building of an organ appropriate in all its parts for the respective species. It has taken us a long time to find this out. It probably would not have taken so long if we had not been so well satisfied with the diagrammatic concept of three brain vesicles." Streeter over-reacted so strongly to the comparative-historical kind of embryology that he even discountenanced, for example, mention of gills in connection

with the branchial bars of the mammalian embryo. At lunch-time discussions in the laboratory he enjoyed being very positive on this and similar topics, although sometimes it appeared that his resistance to phylogenetic embryology was consciously exaggerated for the fun of argument. The positive gain from this attitude will be appreciated if one looks at the illustrations of Streeter's papers, which are completely free from the kind of diagrammatic oversimplification that has so often betrayed embryological thought, as he suggested in the address quoted above. Whenever possible he used a photograph, or had his artist make a realistic drawing. Diagrams were sparingly used and even the most schematic of them were based directly on actual sections.

One of Streeter's studies in comparative embryology was deliberately undertaken because of his critical attitude toward schematic interpretations. At the beginning of the present century some of the comparative embryologists were, as Streeter wrote, "apparently intoxicated by the simplification of the mechanics of development that seemed to be offered by the principle of metamerism," and not stopping their metamerism with the middle germ layer, they were applying it also to other tissues including the medullary tube. There was in fact a definite doctrine of segmentation of the embryonic brain. Some of the most definite claims of this sort having been based upon study of chick embryos, Streeter turned again to the chick. By photographs and dissections of a series of beautifully prepared embryos, he satisfied himself that there is no true metamerism of the brain. The various subdivisions of the developing neural tissue of the head do not reflect the evolutionary history of the region but rather the development of centers of correlation and control, related to the sense organs. He concluded this paper on the status of metamerism in the central nervous system (1933) with the characteristic remark "It is inconceivable that any rigid geometrical scheme could be as marvellous as the reality of the blending adaptation maintained between the embryonic nervous system and the body structures which it is to serve, as they exist at the moment, whereby the two are continuously and perfectly coordinated."

About 1925 Streeter and his colleague Chester H. Heuser began a collaboration that was to last for several years, in research on the early embryology of the domestic pig. The slaughterhouse then operating near the Johns Hopkins Medical School, which years before had provided much of the material for the studies of Mall's pupils, was again utilized. Newly available knowledge of the sow's ovarian cycle facilitated the detection of very early pregnancies.

The superb photography and microtomy of Heuser furnished magnificent preparations from which first Streeter (1927) and then Heuser and Streeter jointly (1929) published papers that together comprise one of the most accurate and complete descriptions of the early embryology of a mammal that has ever appeared. The 1927 paper, which deals with the middle germ layer or mesoblast, is an outstanding example of a method of study frequently necessary in mammalian embryology; that is to say, the application of information gained by experimental workers on the more accessible embryos of oviparous animals to explain what is seen in the mammal. As a competent critic, G. W. Bartelmez, has said, in this monograph Dr. Streeter "succeeded in putting life into boxes of slides."

In 1925 Carl G. Hartman, who had long cherished an ambitious plan of research on the reproductive cycle of the rhesus monkey, the most readily available of the infra-human primates, was persuaded by Streeter to join the Carnegie Department of Embryology and to collaborate with Streeter and Heuser by collecting material for the embryology as well as the physiology of reproduction in rhesus. G. W. Corner had shown, with a little colony of rhesus monkeys adjacent to the Carnegie laboratory, that this species could be maintained and handled under conditions favorable for such an effort. To Hartman's energy and persistence Heuser's masterly knowledge of very early embryos and skilled handling of the material were again added. After eight years of laborious work by all three collaborators, papers on the anatomy and rate of development of early embryos, implantation and membrane formation began to appear. At each annual meeting of the American Association of Anatomists for several years and at two international meetings,

Streeter was present to give one of his charming brief talks on one or another of these topics, illustrated by the incomparable photographs of Chester F. Reather, who had been instructed in this exacting kind of photography by Streeter and Heuser, and by the drawings of the famous Carnegie illustrator, James F. Didusch. The embryological work culminated in two monographs, one by Streeter and George B. Wislocki of Harvard University on the placentation of the rhesus monkey (1938) and the other by Streeter and Heuser on the development of the rhesus embryo (1941). It is not too much to say that this piece of research stands in the front rank of American scientific achievements, by reason of the professional skill lavished upon it under Streeter's leadership by the four investigators, the artist and photographer, by the expert modeler O. O. Heard, by A. G. Rever, who was Hartman's chief aid in breeding and operating upon the animals, and by the rest of the laboratory staff, backed by the Division of Publications of the Carnegie Institution. What embryologist, aware of the difficulties that beset the study of very early embryology even in animals as readily available as the pig, rabbit, guinea pig, and cat, would have predicted in 1925 that by 1950 two primate species (rhesus and man) would be among the best understood of all the mammals as regards their early development?

The great advance in early human embryology made during Streeter's directorship was also a piece of teamwork. Until the 1940's human development before the end of the second week was scarcely known at all. The Miller ovum, of 11 days, described (as above mentioned) in 1926 by Streeter, was the earliest stage in the textbooks. Arthur T. Hertig, who spent a year under Streeter as a Rockefeller Fellow in 1933-1934, returned to Boston and rose to a place of responsibility as pathologist to the Boston Lying-in Hospital and the Free Hospital for Women in Brookline. With the aid of a Carnegie grant he and the scholarly gynecologist John Rock undertook the systematic collection of early human embryos in the large surgical-pathological material of the Free Hospital. The discovery and handling of the individual specimens was of course greatly facilitated by what Hertig had learned from Hartman's and

Heuser's experience in the collection of monkey embryos. Each of the precious specimens was brought to Baltimore for preliminary study and sectioning by Heuser. With increasing acuity in the search, earlier and earlier stages were obtained. During Streeter's lifetime he was able to see the whole picture of human development from about the 7th day on, and to have glimpses of still earlier stages. The great success of the program is now well known to embryologists the world over, from the annual Carnegie Director's Reports and from the papers of Hertig and Rock which have thus far appeared, but the magnitude of the achievement will scarcely be appreciated until the embryos now in hand are fully described and tabulated. In this enterprise Streeter took the part of elder statesman, encouraging and advising but not himself publishing primary reports.

When in 1940 he retired from his directorship, he began at once to work on the culminating task of his career, the preparation of a descriptive catalog and classification of human embryos according to the sequence of development, in order to be able to compare one specimen with another, to judge their age, and to recognize retardations and abnormalities of development. Because embryos undergo extreme transformations of shape while growing rapidly in size, they cannot be classified by any dimensional measurement that is comparable through all the stages from the egg to the fetal period; nor are there any anatomic features that are available throughout. The somites for example do not begin to develop until day 20, and become useless for dating the later stages because the addition of new somites ceases before the end of the embryonic period. It is necessary to define the successive stages by taking account of a whole series of details; for example the appearance of pigment in the optic cup, the first sign of a limb bud, the closure of the otic vesicle, etc. Accurate descriptive norms and profuse illustrations are required. This "Normentafeln" method of classifying embryos has long been available though not intensively used. In the case of the human species accurate norms have been unavailable for lack of sufficient material. It is impossible, therefore, when reading many papers on mam-

malian and especially human embryology, to find out the precise stage of development of the embryos studied.

Streeter began his work on the "Developmental horizons in human embryos" by revising a tentative assignment of stages of human embryonic development made long ago by F. P. Mall for this purpose. He set up 23 stages or "horizons" from the one-cell egg to the end of the embryonic period, which he arbitrarily defined as ending when marrow formation is clearly discernible in the femur. This occurs at about 48 days, ovulation age. He chose to start his descriptions at Horizon XI (13 to 30 somites), leaving the earlier stages for later consideration. Working assiduously during the eight years Fate granted him, he prepared four articles covering Horizons XI to XVIII. When he was stricken by fatal illness the illustrations and notes for another section of his survey were on his drawing table. That section, covering stages XIX to XXIII, has been completed by two of his colleagues (Heuser and Corner), and work is under way on the first 10 stages. The published articles form a continuous description of the external form and major internal structures of the human embryo during the latter half of the embryonic period, with a catalog of the useful embryos of each stage in the Carnegie Collection, profusely illustrated with photographs and line drawings. Streeter selected those features which were changing most rapidly at a given time, to characterize that particular stage of development. With the aid of his photographs, diagrams and tables it is readily possible to check the relevant characteristics of an embryo and assign it to its place in the series of growth stages, much as in using a taxonomist's key in identifying species of plants or animals. The text, as mentioned above, also includes a great deal of new descriptive material, especially on the development of the heart and of bone tissue. This exceedingly instructive and useful task could have been accomplished by no one else, and only with the great collection that had been assembled under Streeter's leadership.

The story of his scientific career must also include a word about his influence upon guest investigators who came from many States of the Union and foreign countries to work with

Streeter and his colleagues. All of these visitors developed an affectionate regard for Dr. Streeter. Their numerous research reports in the Carnegie Contributions to Embryology and elsewhere are sufficient proof of his always generous and helpful leadership. Severely critical as he was, he never considered embryology an esoteric craft, and was always ready to provide ways and means for investigation by serious people.

Streeter's enthusiastic desire to communicate his knowledge to interested listeners made him a very good speaker in spite of his innate shyness. His full-length lectures were models of graceful exposition, but his immediate colleagues will perhaps most happily recall his almost annual appearances at the Anatomists' meetings, when he modestly took his twelve-minute turn, presenting each time one carefully chosen topic from his recent work, clearly stated and beautifully illustrated, clinching the single point once for all.

He had rather austere views about the matter of bringing science to the public, feeling that front-rank investigators like those of his laboratory ought to inform physicians and medical school and college teachers about the results of their research, but are not called upon to write or speak at a more popular level. His publications therefore include only a few lectures before general audiences and articles written for scientific magazines. Though excellent in style and characteristically well illustrated, these articles make no effort at superficial appeal.

Dr. Streeter considered scientific research the highest human activity. He never wished to do any other kind of work. Administration was something that had to be done to keep research going. In business affairs he was thorough and cautious. Avoiding difficulties by forethought, he seldom had to act drastically. He did not seek outside responsibilities but cheerfully accepted such as he felt were matters of duty. He was for several years Chairman of a Division of Animal Biology that was set up within the Carnegie Institution for administrative purposes. He served the National Academy of Sciences as chairman of several committees. A call to civic service in Baltimore as member and subsequently President of the Board of the Samuel Ready School, an endowed residential school for

girls, greatly touched him and he devoted himself generously to its management. His sense of form and good taste enabled him to take an active part in the planning of three fine buildings, the new wing of the Carnegie Institution administration building in Washington, with its effective Elihu Root Auditorium, the Samuel Ready School in Baltimore, and the modern home which he and Mrs. Streeter built in 1937 at 3707 St. Paul Street, Baltimore. In later years his counsel was much sought by younger colleagues, by fellow investigators, and by his successor in the directorship. He was always willing to discuss their problems, but would never let a scientific visitor go without turning again to his microscope and drawings, with gentle insistence ending the interview with an embryological discourse on whatever he was studying at the time.

It is a pity that no one ever made a "candid camera" picture of him in one of these moments of bright enthusiasm. He was shy before the camera and there is no photograph that shows his characteristic cheerfulness and alertness. His personal charm, compounded of courtesy, thoughtfulness, and a kind of happy buoyancy, won the affection of everyone who knew him well. He was reticent with strangers but an enthusiastic conversationalist with intimates. His ideas and convictions, which were conservative in matters of politics, finance and social controversy, but often venturesome in scientific matters, were seldom expressed directly. Because of his diffidence, he found it easier to hint at his own views, and to elicit those of others, by unexpected remarks and questions, fundamentally thoughtful but often humorously exaggerated, impish, or contrary. This method of discourse was sometimes surprising to new acquaintances but it was free from malice and those who could take it were always rewarded by a spirited conversation and by generous consideration of their own opinions.

Dr. Streeter's achievements and services were recognized by many honors. He was elected to the National Academy of Sciences in 1931 and to the American Philosophical Society in 1943. His professional colleagues in the American Association of Anatomists made him their President (1926-1928). In 1928 he was elected Fellow of the Royal Society of Edinburgh.

Trinity College, Dublin, in 1928 gave him the honorary degree of Doctor of Science, as did his own college, Union, in 1930. The University of Michigan, where he taught for seven years, made him LL.D. in 1935.

The always fortunate circumstances of his professional career were matched by his happy family life. While at Ann Arbor he married (1910) Julia Allen Smith of that city, a lady particularly fitted by her own talents for graphic art to understand and encourage his work. Their son and one of the two daughters have followed their father in the medical profession. The elder daughter took her doctorate in chemistry.

This lifetime of uninterrupted achievement, so calm in its outward aspects, so full of the inner excitement that comes from scientific discovery, came to a quiet end on July 27, 1948, when Dr. Streeter, on vacation in his Adirondack summer cottage, was stricken without warning by a heart attack. On the last day of his life his microscope and his drawing board were at hand, and he was still studying the marvelous processes of human embryonic development.

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

- Albany Med. Ann.=Albany Medical Annals
 Amer. Jour. Anat.=American Journal of Anatomy
 Amer. Jour. Obstet. Gynecol.=American Journal of Obstetrics and Gynecology
 Anat. Anz.=Anatomischer Anzeiger
 Anat. Rec.=Anatomical Record
 Arch. f. mikr. Anat.=Archiv für mikroskopische Anatomie
 Ber. des Inst. Internat. d'Embryol.=Berichte des Institute International d'Embryologie
 Brit. Med. Jour.=British Medical Journal
 Bull. Johns Hopkins Hosp.=Bulletin of Johns Hopkins Hospital
 Carnegie Inst. Wash. News Serv. Bull.=Carnegie Institution of Washington News Service Bulletin
 Carnegie Inst. Wash. Year Book=Carnegie Institution of Washington Year Book
 Contrib. Embryol.=Contributions to Embryology
 Jour. Amer. Med. Assn.=Journal of the American Medical Association
 Jour. Comp. Neurol.=Journal of Comparative Neurology
 Jour. Exper. Zool.=Journal of Experimental Zoology
 Phys. Surg.=Physician and Surgeon
 Proc. Inst. Med. Chicago=Proceedings, Institute of Medicine of Chicago
 Proc. Nat. Acad. Sci.=Proceedings, National Academy of Sciences
 Proc. Soc. Res. Child Develop. Nat. Res. Coun.=Proceedings, Society for Research in Child Development, National Research Council
 Sci. Mo.=Scientific Monthly
 Trans. Amer. Otol. Soc.=Transactions, American Otological Society
 Trans. Stud. Coll. Phys. Phila.=Transactions and Studies, College of Physicians of Philadelphia
 Verhandl. d. anat. Gesellsch.=Verhandlungen der anatomischen Gesellschaft

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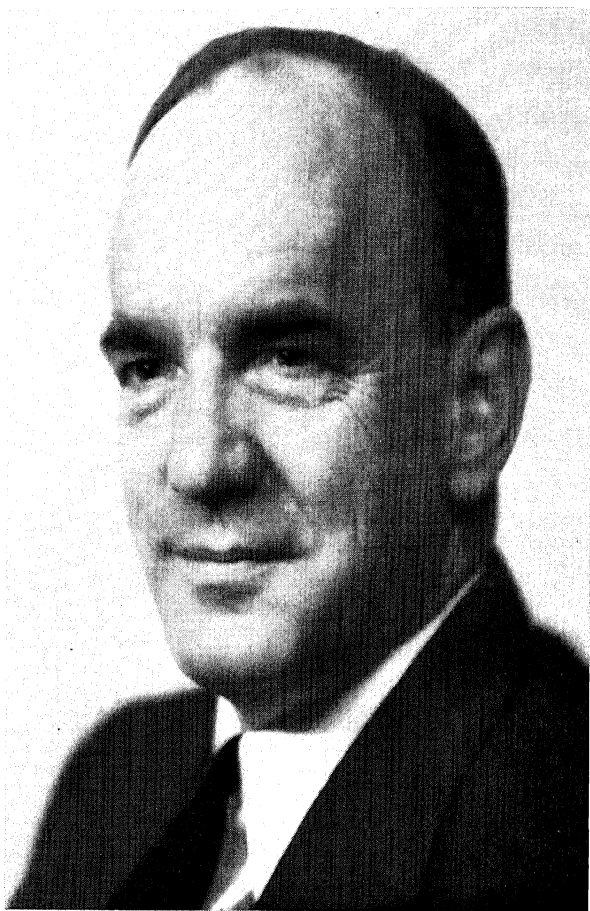
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Samuel H. Hays

FRANK CLIFFORD WHITMORE

1887-1947

BY C. S. MARVEL

Frank Clifford Whitmore was born in North Attleboro, Massachusetts, on October 1, 1887. He spent his early youth in Atlantic City, New Jersey, and there received his grammar and high school training. His mother was a remarkable woman who found time in a busy, workaday life to interest her son in Shakespeare and classical literature. He retained throughout his life, an interest in literature and a tremendous variety of other subjects.

Whitmore selected the Latin-Scientific course in high school as preparatory for college. But when, at the beginning of his senior year, he chose Harvard as his college, he expected to need a year of Greek for entrance. Characteristically, he persuaded the high school principal to give such a course. Whitmore was the leader of his class in academic work and in athletics. He was captain of the track team and was active in basketball. He achieved unusual skill in the craft of wood carving. He graduated in 1907 as valedictorian of his class and was awarded a scholarship to Harvard University. It was in high school that he acquired the nickname of Rocky Cliff, from his middle name, Clifford. This was later shortened to "Rocky" by which he was known throughout life.

He was proud of having worked his way through Harvard, and showed great ingenuity in finding jobs of various types. He was particularly fond of telling about a job as night telephone operator at the switchboard in the town of Wellesley, Massachusetts some 17 miles from Harvard Square. He travelled between the towns by trolley car and was on duty from 7 p.m. to 7 a.m. daily. He held this job for the balance of his freshman year. He ingeniously contrived a device that rang a bell instead of merely showing the usual light whenever a subscriber lifted his receiver. Thus he was able to do his studying and get his necessary sleep between calls. Fortunately, the exchange was not a busy one.

He took no chemistry as a freshman but did start the study of that subject as a sophomore. Between his junior and senior years, he tried for a place as a college guide and served in that capacity during the summer of 1910. It was during this summer that he decided to make chemistry his life work. In his senior year he took nothing but chemistry—qualitative, quantitative, organic, and physical—and received his A.B. *magna cum laude* in June, 1911, and his A.M. with highest honors June, 1912. He attracted the attention of Professor Charles Loring Jackson and became his laboratory assistant. This was Whitmore's introduction to research. He had to work with unusual independence, for Professor Jackson was about to retire and spent most of his time at his home in Prides Crossing, Massachusetts. Whitmore went there for many conferences on his research problem.

In 1912, after Professor Jackson's retirement, Whitmore shifted his work to Professor T. W. Richards and Professor Kohler. During his graduate work he supported himself as a very active tutor in the famous "Widow's" tutoring school. He was highly successful and commanded what was a very large salary for the times.

While a graduate student he decided definitely on an academic career. However, his income as a tutor was much more than he could expect as an instructor in any college at that time. Consequently, he devoted two years after receiving his Ph.D. degree in 1914 to tutoring in order to accumulate enough money to live on his savings and a university salary thereafter.

In 1914 he married Marion Gertrude Mason of Cambridge. He had met his wife-to-be during his summer as a university guide. She was a student of chemistry at Radcliffe and became a great help to him first in the laboratory and during later years in the writing of his books and papers. They were a very devoted couple throughout their married life, with five children, Frank, Jr., Mason, Harry, Marion, and Patricia Joan (deceased).

It is of interest to note that all four children have turned to scientific careers. Frank, Jr. was trained at Amherst, Pennsylvania State College and Harvard (Ph.D. 1942) in geology

and currently is Chief of the Military Geological Branch of the U. S. Geological Survey. Mason received the M.D. degree from Cornell University and is now resident in radiology at Jefferson Hospital in Philadelphia. Harry was trained as a chemist at Pennsylvania State College and is in the technical sales and service department of Universal Oil Products Company, where he is the expert on food anti-oxidants. Marion has completed her work for the degree in the premedical course at Pennsylvania State College and is now studying with Dr. Pauline Beery Mack in the field of nutrition.

In 1916-17 Whitmore was instructor at Williams College and in 1917-18 he taught at Rice Institute. He worked at Rice Institute on toxic gases for the Chemical Warfare Service. He went to the University of Minnesota as Assistant Professor in 1918 and remained two years. He next was called to Northwestern University as Professor in 1920. Here he was associated with Professor W. Lee Lewis. When Lewis left the University, Whitmore was made Head of the Department. At Northwestern, Whitmore began to have graduate students working with him and soon his scientific work began to attract attention. He obtained a grant from the Interdepartmental Social Hygiene Board and began intensive work on the organic mercurials. His first book, a comprehensive treatise on organic mercury compounds, appeared in 1921. He concentrated his researches in this field during his stay at Northwestern.

Whitmore was an extremely vigorous person and a prodigious worker. He not only carried his duties as Head of the Department at Northwestern and conducted an aggressive research program, but was able to serve as a consultant to the Bureau of Chemistry and Soils of the Department of Agriculture and to the Chemical Warfare research group, as a member of the editorial board of *Organic Syntheses*, as editor of the *Chemical Bulletin*, in many capacities for the National Research Council (Chairman, 1927-28) and in all elective offices of the American Chemical Society, including five years as Secretary of the Organic division. While at Northwestern he again demonstrated that he could do with little sleep compared with most men. He got up as early as 3:00 a.m. and went to work in his

office. Then at normal times for rising he returned home to be with his family for a few hours before returning to his regular office schedule.

In 1929 he moved from Northwestern to the Pennsylvania State College as Dean of the School of Chemistry and Physics and Research Professor of Organic Chemistry where he remained for the rest of his life. He raised the standards in chemistry to give Pennsylvania State College a high place in chemistry and chemical engineering education. While he was Dean there, the graduate enrollment in chemistry increased from 18 to over 100 and the College awarded 871 Bachelor's, 383 Master's, and 215 Doctor's degrees in chemistry and chemical engineering. In spite of heavy administrative duties, he managed to remain an inspiring and thorough teacher, increased his output of fundamental research in many fields of organic chemistry, and at the same time carried on his service to the American Chemical Society as a director, president, and associate editor of its journal. While president of the American Chemical Society he visited and talked before each of its over one hundred sections.

During World War II, he was especially active in a wide variety of Government projects. For the National Defense Research Committee, he served as chairman of the subdivision of the chemistry section dealing with organic explosives during the critical early years of that program. He served as consultant to the War Manpower Commission, War Production Board, Office of Production Research and Development, and Office of the Quartermaster General. In addition, he supervised war research at Pennsylvania State College dealing with aviation fuels, lubricants, explosives, antimalarials, synthetic rubber, penicillin, and silicones. He was particularly active in his support of the efforts to keep the Selective Service System selective so that the highly trained personnel in chemistry, chemical engineering, and physics could be used where they would be of greatest service to the country. It can be said with truth that Whitmore was a war casualty, for the heavy drain on his vitality that all of these activities required resulted in his physical decline and led to his sudden death. For his con-

tribution to the war he was awarded the President's Certificate of Merit, posthumously.

Whitmore was an unusually productive man in the field of fundamental organic research. As was mentioned, his first independent work was in the field of organic mercurials. His monograph in that field published in 1921 is still the standard reference text. He not only devised many new mercurials but in particular he developed better methods for the production of many types of mercurials and showed how these materials could be used to advantage for the synthesis of many other types of organic compounds.

Perhaps his best known work was in the field of molecular rearrangements. His electronic conception of rearrangements has become generally accepted by all organic chemists, although when first proposed many were skeptical of its ultimate usefulness. In establishing this conception of rearrangements on a firm experimental basis, Whitmore directed his researches into nearly every phase of synthetic aliphatic chemistry. He prepared hundreds of new and complex alcohols and studied their dehydration products. In the synthesis of the needed alcohols he improved old procedures and developed new ones. In particular he added to our knowledge of the Grignard reaction as a source for ketones from acid chlorides, for the preparation of tertiary hydrocarbons, and as a reducing agent. He devised improved procedures for the ozonolysis of unsaturated hydrocarbons in order to elucidate the structure of his rearrangement products. He developed the unusual chemistry of the neopentyl system which was essentially unknown before his researches in that field. He synthesized pure hydrocarbons, both saturated and unsaturated, to confirm their properties and structures. He related the rearrangements of olefins in acid solution to the rearrangement involved in the dehydrogenation of alcohols by various agents, and the rearrangements which occur in such reactions as the Hofmann degradation of amides, the Chugaev reaction, the transformation of tertiary halides, the pinacol and semi-pinacol rearrangements, action of nitrous acid on amines, the cationic polymerization of olefins and other similar transformations.

In the field of antimalarials, he synthesized a wide variety of heterocyclic bases in the pyridine, pyrimidine, quinoline and triazine series. His wartime studies of the organosilicon compounds led to many new synthetic procedures and in particular he discovered the unusual activity of β -substituted organosilicon derivatives. In the development of processes, he contributed to the processing of penicillin, the production of benzyl chloride by the chloromethylation of benzene, and a pilot plant study of the production of benzyl benzoate. He also conducted pilot plant studies on the preparation of RDX which were used as the basis for one of the first plants built for the production of this explosive. The first hundred pounds of RDX were made in Whitmore's laboratory. In addition to these particular studies in the fields of his greatest interests, Whitmore contributed to nearly every field of organic chemistry.

The investigation of organosilicon compounds interested him so much that at the time of his death he was planning a twenty-year research program in this field. It was his intention that the silicon studies should constitute the third major phase of his research career after the mercurial and hydrocarbon work.

In 1937 his textbook "Organic Chemistry" was published. He characterized it as a one-volume "Beilstein" and directed it toward the advanced group of students and practicing organic chemists. This treatise reflected current industrial interest in the aliphatic and alicyclic series of compounds since nearly three-fourths of its pages were devoted to these topics. The book has had a wide acceptance and is another of Whitmore's important contributions to organic chemistry. A second edition was in preparation at the time of his death, and this has now been completed and made available to all through the efforts of his family.

His researches were recognized by many honors conferred by his fellow chemists. He was awarded the William H. Nichols Medal by the New York section of the American Chemical Society in 1937; was elected in 1938 to the Presidency of the American Chemical Society and to honorary membership in the professional chemical fraternity, Phi Lambda Upsilon; was elected to the American Philosophical Society in 1943; was

awarded the Willard Gibbs Medal by the Chicago Section of the American Chemical Society in 1945. He was elected to the National Academy of Sciences in 1946. He was granted honorary Doctor of Science degrees by Franklin and Marshall College and by the University of Delaware in 1937, and by Allegheny College in 1938.

Although he was awarded most of the honors that can come to a scientist, Whitmore was much more willing to discuss his less spectacular successes, such as being a member of the Atlantic City High School relay team that won a first place in the 1906 Penn Relays, of his skill in bicycle races on the lot where now stands the Claridge Hotel in Atlantic City, and of his activities in the Webster-Haines Debating Society in high school days.

He was always the modestly human man who liked people and who liked chemistry. His recognition as a scientist came naturally because of these interests and not because he sought honors.

He found time in the midst of his many duties to advise industry on its difficult problems. He kept in touch with his students and was always willing to advise them on technical and personal problems. He was always eager to see his "boys" advanced to make best use of their talents. His loyalty to his family extended to those who were his students and his friends. He never was too busy to help any one of those associated with him. He was always cheerful, inspiring, even-tempered, enthusiastic and full of energy. Dean Whitmore's career was ended by his sudden death at his home on June 24, 1947. The tribute paid him by the Directors of the American Chemical Society describes him as "a scholar, teacher, original investigator, dean, eminent scientist, and inspirational leader . . . a great man who gave himself freely to the welfare and advancement of his fellow men and to the advancement of chemistry".

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

- Ber.=Berichte der deutschen chemischen Gesellschaft
 Chem. Bull.=Chemical Bulletin
 Chem. Eng. News=Chemical and Engineering News
 Chem. Ind.=Chemical Industry
 Ind. Eng. Chem.=Industrial and Engineering Chemistry
 J. Am. Chem. Soc.=Journal of the American Chemical Society
 J. Chem. Ed.=Journal of Chemical Education
 Org. Syn.=Organic Syntheses
 Rec. trav. chim.=Recueil des travaux chimiques des Pays-Bas et de la Belgique
 Sci. Mo.=Scientific Monthly
 Sci. Petro.=The Science of Petroleum

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